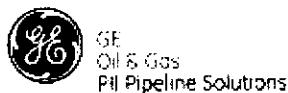


APPENDIX V

Engineering Critical Assessment of USCD Reported Defects and Excavation Findings, Revision 6, August 23, 2006, (72+cover sheet)



REPORT

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Engineering Critical Assessment of USCD Reported Defects and Excavation Findings

For

Dixie Pipeline

12-inch Line Hattiesburg to Demopolis

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August 23, 2006

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Revision: 6



Executive Summary

Dixie Pipeline Company operates a 12-inch propane pipeline, which runs from Hattiesburg to Demopolis. The pipeline was constructed from API 5L Grade X52 Electric Resistance Welding (ERW) line pipe. This pipeline segment has been found to be susceptible to seam weld defects, i.e., lack of fusion, at certain locations between Hattiesburg and Demopolis pump stations. As part of an ongoing integrity program, Dixie contracted GE to conduct a seam weld inspection utilizing the UltraScan Crack Detection (USCD) tool. Subsequently, GE performed an Engineering Critical Assessment (ECA) of the features to determine which seam weld defects were significant in relation to the integrity of the line and to establish a remediation program for those found to be sub-critical.

This report describes the findings of the re-assessment of the 2005 USCD data on the basis of the excavation findings and determines:

- The significance of USCD reported features and field defects at the MOP of 1440 psi;
- The effects of fatigue loading on the assessed defects; and
- A remediation and monitoring program.

Based on the preliminary Engineering Critical Assessment, Dixie excavated 41 sites to determine the sizes and characteristics of the features reported by the USCD inspection to allow a more accurate re-assessment. The excavation program confirmed that:

- features reported as mill trim tracks, surface breaking laminations or probable weld defects could be associated with crack or lack of fusion;
- notch-like USCD calls could be associated with cracks, or lack of fusion.

On the basis of the field data, all notch-like features have been sized and assessed as cracks. Crack-like features with comments of "mill trim tracks", "surface breaking laminations", or "probable weld defects" are assessed by crack assessment method. Other field findings are described in appendix.

In addition, all in-weld features have been sized. After the re-analysis of the USCD data of crack-like or notch-like, 570 features in the base metal, 13274 features adjoining the weld, 494 features in the weld, and 19 features in 'not-decidable' locations, were reported and sized. The assessment of the excavated ILI features has been replaced by that of the field indications, which provided more complete and accurate measurement.

Upon Dixie Pipeline engineer's request, the nominal wall thickness has been used in the assessment to replace the USCD tool measured wall thickness. The footage of nominal wall thickness from data sheet provided by Dixie has been linearly corrected to correlate with the USCD inspection distance. The nominal wall thickness data is then assigned to the USCD features. It has been found that 11 features are located in heavier wall pipes. None of the USCD features is located in seamless pipe. Since the toughness of heavier wall pipe is



unavailable, these 11 features have been considered separately. The remaining USCD crack-like and notch-like features are assessed based on the USCD reported sizes by the FAD level II approach.

On the basis of the data collected in field, 163 cracks, and 129 lack of fusion defects have been assessed as cracks using the FAD level II approach. 143 laminations have been assessed according to the API 579 lamination assessment methodology.

The numbers of features unacceptable at the MOP (1440 psi) are shown in the following table, and have been ranked, based on feature severities.

	Number of unacceptable features
Crack-like features adjoining weld (aw)	174
Crack-like features in weld (iw)	16
Notch-like features adjoining weld (aw)	26
Crack found in field	9
Lack of fusion found in field	2
Total	227

It is recommended in priority order that Dixie:

- repair the 9 cracks, and 2 lack of fusion defects, which have been assessed as unacceptable on the basis of the 2005 excavation program;
- investigate the 174 adjoining weld crack-like (cl) features, 16 in weld cl features, 26 adjoining weld notch-like features that are unacceptable at the MOP 1440 psi;
- check alignment data for the lamination (Joint 329, feature ID 138) at a distance of 16371.19 to 16372.03 ft and repair if it is associated with a major structural discontinuity;
- check pipeline record or perform toughness or CVN test for heavier wall pipe, and then decide whether the 11 heavier wall USCD features are acceptable.

A fatigue analysis was conducted using standard fracture mechanics approach with the pressure cycling data supplied by Dixie, and simplified Rainflow Counting Methods. An excavation plan has been prepared for the unacceptable features and sub-critical features which are predicted to grow to an unacceptable size. Features in the same pipe joint or closer than 40 feet in adjoining pipe joints are considered in one excavation. The unacceptable features are ranked based on their severity to optimize the excavation program. The numbers of cumulative excavations in the following years are provided.

The pipeline should be re-inspected with an ILI tool or hydrostatically tested. Dixie Pipeline Company can select the appropriate re-inspection interval based on the costs and number of excavations. Data from ongoing excavations can be used to determine whether the re-assessment interval needs to be revised. If significant changes to the operating conditions and cyclic pressure are identified, the fatigue analysis should be repeated.



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1. INTRODUCTION

Dixie Pipeline Company operates a 12-inch diameter pipeline, which transports propane from Hattiesburg to Demopolis. The pipeline was constructed from API 5L Grade X52 Electric Resistance Welded (ERW) pre-1970 line pipe. During a re-qualification hydrostatic test program carried out in 1984 between Hattiesburg and Demopolis pump stations, a number of seam weld related failures occurred. This pipeline segment has therefore been identified as at risk from seam weld defects. As part of an ongoing integrity program, Dixie contracted GE to conduct a seam weld inspection utilizing the UltraScan™ Crack Detection (USCD) tool^[1].

Subsequently, GE performed an Engineering Critical Assessment (ECA) of the reported features to determine which seam weld defects were significant in relation to the integrity of the line and to establish a remediation program for any sub critical defects. At the same time, Dixie conducted a program of excavations to validate the findings (see Section 3) of the inspections and to provide additional data for a more accurate assessment.

The pre-assessment performed by GE in October 2005 identified 55 critical features. The engineering critical assessment has thereafter experienced several stages.

- The assessment was updated using a constant pressure of 1440 psi along the full length of the pipeline to take account of an unplanned shut-in condition. (December 2005)
- New fracture toughness data for the heat affected zone was measured and was applied in the assessment. Assessment is provided with and without tool tolerance. (February 2006)
- Assessment was updated based on the field inspection findings^[2]. Tool tolerance of depth was excluded. The field indications were also included in the assessment. (March 2006)
- Notch-like features were sized and included in the assessment. (May 2006)
- GE reanalyzed USCD inspection signals and provided new feature list. Assessment was repeated based on new list. (July 2006)

In each stage, the assessment results were then presented to Dixie. In this revision, the assessment is repeated based on nominal wall thickness upon Dixie Pipeline Company engineer's request.

Based on the above work, this report describes the findings of the final assessment of the 2005 USCD reported crack-like and notch-like features along with the excavation findings, and determines:

- the significance of the seam weld defects reported by USCD tool and field findings in relation to the MOP of 1440 psi;



- the effects of fatigue loading on the seam weld defects and field findings; and
- a remediation and monitoring program.

This assessment will allow the development of a short and long-term remediation program and integrity management strategy for the seam weld defects.



2. PROCEDURES FOR ENGINEERING CRITICAL ASSESSMENT

Background

This section presents the approach and inputs used to perform an ECA of crack features. The immediate threat that crack-like and crack field features pose to the pipeline was assessed using fracture mechanics based on a Failure Assessment Diagram (FAD) as presented in the recommended practice API 579-2000 [3].

The API 579 FAD approach outlines fracture mechanics methods for analyzing the acceptability of flaws in many types of structures and components. Three levels of assessment are described in the recommended practice: Level-I, the simplified assessment method, Level-II, the normal assessment method and Level-III, a ductile tearing instability assessment. The advantage of the API 579 approach is that it is a two-parameter failure assessment that considers failure through both (brittle) fracture and net section (plastic) collapse simultaneously.

The Level-II fracture assessment methodology described below and illustrated in Figure 1, was used to assess the acceptability. The vertical axis of the FAD is the ratio (K_r) of the applied stress intensity factor K (or, applied J-integral J , or crack tip opening displacement CTOD) to the material's fracture toughness K_{MAT} (or J_{MAT} , or CTOD critical). The horizontal axis is the ratio (L_r) of the applied stress to the plastic collapse stress (generally the SMYS). In order to assess the significance of a particular flaw in a structure, one must determine the values of K_r and L_r associated with that flaw, and plot the point on the diagram. If the assessment point lies outside the area bounded by the axes and the assessment line, the flaw is said to be unacceptable; however if it lies inside the line, the flaw is acceptable. A cut off on the horizontal axis is incorporated into the assessment to prevent localized plastic collapse.

The FAD shows the proximity of a planar defect to plastic collapse (L_r is typically between 1.0-1.3) and brittle fracture ($K_r = 1$). It gives a visual indication of the acceptability of the defect at the combination of stress, feature dimensions and material properties specified. The closer the defect lies to the FAD curve, the higher the risk of failure. Repeated calculation allows critical crack depths to be determined as a function of crack lengths.

The results of the failure assessment diagram Level-II are generally conservative and appropriate for assessing the fitness-for-service of pipeline features such as seam weld defects and crack-like features. Thus, an FAD Level-II assessment was used in this ECA. However, for materials that exhibit stable crack growth, by ductile tearing, the fracture toughness increases with crack growth, which is not taken into account by FAD Level-II. The actual failure condition for a pipeline containing cracks, which exhibit ductile tearing prior to failure, can be more precisely assessed by employing a more accurate, Level III FAD approach as described in detailed in the Appendix. However, to conduct such a Level III



assessment, detailed material properties in the location of the defect are required, for example true stress-strain curve and the fracture resistance of the pipe material.

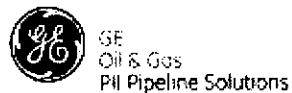
In this assessment, Partial Safety Factors are not used, because conservative assumptions are made in determining the materials fracture toughness and applied stress. For features at weld joint, the weld joint efficiency has not been considered, because the fracture toughness was measured in weld and is used in the assessment.

Input Parameters

The assessment pressure used in this report was the maximum operating pressure (MOP) of 1440 psi applicable to both segments Hattiesburg to Carmichael and Carmichael to Demopolis.

The USCD tool reports defects in 4 groups, <12.5%, 12.5 – 25.0%, 25 – 40%, and >40%. The upper limit of each group of features has been used in the assessment. In-field defect dimensions have been used for the assessment of field indications.

The fracture toughness properties of the line pipe under consideration were measured from pipe material removed from the system following the ASTM standard test method E1820 [4]. Three samples were measured from each of base metal (bm), seam weld (iw), and heat-affected zone (HAZ), and will be used in the assessment of "bm", "iw" and adjoining weld (aw) features, respectively. The fracture toughness values at HAZ were measured [5] by taking samples 0.25 inch away from the bond line. The lowest of three readings for each area was used in the assessment. For conservativeness, the minimum specified yield strength of the pipe was used as the yield strength with the corresponding tensile strength as recommended by API 5L specification. The material properties are summarized in Table 1.



3. FIELD EXCAVATION FINDINGS

3.1 Field Excavation

As part of the integrity program, an excavation program was conducted to confirm the characteristics and dimensions of the reported features. 41 sites were excavated and 102 features were inspected (2 dents and 1 feature which was not inspected have been excluded from this number). Table 2 shows the locations and findings of the manual NDE inspection from the excavations.

The in-field defect verification was conducted as follows:

- Each feature was inspected using magnetic particle, visual examination, and manual ultrasonics.
- A total of 56 USCD features in 17 joints were then inspected by Phased Array Ultrasonics Technique (PAUT) to provide detailed data for the defects in the areas adjacent the reported features.

The field measurements associated with each USCD feature, were provided in 41 dig reports [6]. The results of these 41 dig reports are summarized in Table 3. The key findings of the excavations are detailed below.

3.2 Field Findings

Groups of the excavated USCD features

In the USCD feature list, comments were provided for these features, such as mill trim tracks, surface breaking laminations, etc. The 102 field-inspected features are grouped according to the comment, to compare with field findings, in order to optimize the assessment.

The 102 USCD features which were excavated were classified into the following groups: "mill trim tracks", "surface breaking laminations", "possible weld defects", and "probable indications from the weld". If the excavation findings confirmed that they were not associated with cracks or lack of fusion, they can be excluded from the assessment.

11 of the 102 excavated features were reported by the USCD tool as mill trim tracks; all of these features were associated with cracks. In addition, lack of fusion defects and grooves were also reported. On this basis, features reported as mill trim tracks have been assessed as cracks.

8 of the 102 excavated features were reported as surface breaking laminations (including one feature classified as both a surface breaking lamination and a possible weld defect). 2 of these were associated with cracks, 4 were lack of fusion, 1 was an inclusion, and 1 was a



sliver. On this basis, the USCD reported crack-like features that are commented as laminations will be conservatively assessed by crack assessment method ¹.

34 of the 102 excavated features were reported as possible weld defects. 25 of these were lack of fusion defects, and 7 were associated with cracks, 1 was a lamination, and 1 was internal metal loss. On this basis, USCD features reported as possible weld defects will be assessed as cracks.

39 of the 102 features were reported as probable indications from the weld. 28 of these features are lack of fusion defects, 4 are associated with cracks, 3 features are internal metal loss, 3 features are characteristic of misalignment and 1 feature is associated with Roller/Tool Marks. On this basis, USCD features reported as probable indications from the weld will be assessed as cracks.

The remaining 10 of the 102 features can not be classified within these groups. On the above basis (see Table 2), USCD features that are reported as mill trim tracks, surface breaking laminations, or probable indications from the weld, are conservatively assessed as cracks.

Tolerances

Upon Dixie Pipeline Company engineer's request, the nominal wall thickness is used in the assessment. The nominal wall thickness is usually greater than the wall thickness measured by the USCD vehicle. By comparing these two values of the wall thickness, it was found that only for 118 of 14280 features the wall thicknesses by USCD inspection are greater than the nominal wall thickness. Since the feature depth provided by USCD was in percentage of wall thickness, the feature depth calculated from the nominal wall thickness will be usually greater than the value provided by USCD inspection.

On this basis, the assessment has been conducted on the basis of the in-field defect measurements, and on the basis of the USCD reported sizes without the inclusion of depth tolerance but with the length tolerance as detailed above.

A comparison of the USCD reported depths and the depths based on excavation findings has been conducted. The result is described in appendix.

¹ The USCD tool reported these features as crack-like, with an associated comment of "probable surface breaking lamination/slivers". However, the confidence level is unknown for the classification of "probable surface breaking lamination/slivers" as opposed to crack-like. Therefore, such USCD reported features are treated as crack-like features.



Notch-like and not-decidable features²

The reported USCD features that were excavated were compared with field indications in order to find potential correlations which would then optimize the assessment of USCD features. It can be seen from Table 2 that the notch-like features might be associated with crack or lack of fusion. Based on these findings, the notch-like features were recommended for sizing and therefore, have been assessed in this report.

1 of the 25 not-decidable features is associated with a crack (pipe joint 5073, feature LIN-02). However, the depth (0.038 inch) of the crack is less than the USCD sizing limit (0.04 inch). Since not-decidable features are very unlikely to have crack characteristics, they are not considered in engineering crack assessments.

Repaired features

During the excavation program, some features were repaired if they failed to meet Dixie Pipeline Company's screening criteria.

The feature LIN-01 located at an absolute distance of 16057.87 in pipe joint 324 was repaired during the excavation program. 3 USCD features which are located in this pipe joint (04-00408, 04-01286, 04-01292) have therefore been excluded from this assessment. Remediation was also required at pipe joint 6903 following excavation and measurement. On this basis, 4 features (29-00117, 29-00130, 29-01168, 29-01169) at this joint site are not assessed in this report. The repair of these 2 joints is recommended in digs reports^[6]. These repaired features are based on GE-IS inspection reports. Any features that were repaired prior to or after the GE-IS inspection are not included in GE-IS inspection reports, and therefore have not been addressed in this report.

A Dixie Pipeline Company's engineer stated^[7] that repairs were also performed on pipe joint 5204 and 6418 following excavation and measurement from GE-IS. It was also stated that one dent (feature 69-00984 in joint 10639) was reported as adjoining the seam weld and with possible cracking; this was classified as an immediate repair by Dixie. Detailed information on the extent of the repair in this spool is not available and consequently all the features, which were reported in this spool, have not been distinguished in the assessment.

² Due to the nature of USCD signal, some features cannot be decided against current feature classifications. These features are classified as "not-decidable" features.



4. ALIGNMENT OF NOMINAL WALL THICKNESS TO USCD INSPECTION

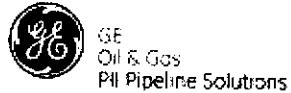
The Dixie Pipeline Company engineer provided a document of nominal wall thickness for the pipeline from Hattiesburg station to Demopolis station. This data sheet is based on a caliper inspection conducted by a third party so that the absolute distance in the data sheet does not directly match the distance in USCD inspection. With the agreement of Dixie Pipeline Company engineer [8], the absolute distance in the data sheet is linearly corrected to match the USCD absolute distance. In other words, the start and end points in the Caliper inspection are set to match the distances in the USCD inspection. Then the other distances in the Caliper inspection are linearly corrected. Table 6 shows the corrected distance of the nominal wall thickness.

With this corrected footage, the nominal wall thicknesses by the Caliper inspection are plotted together with the wall thicknesses measured by the USCD vehicle, shown in Figure 2. It can be seen that most of the 0.375 inch heavier walls correlate well with those measured by USCD inspection, except at distance of 3088, 4237, 534913 and 612069 feet. For these correlated heavier wall pipes, features are manually identified according to the USCD measured wall thickness, usually greater than 0.3 inch. And then, the nominal 0.375 inch wall thickness is assigned to these pipes. The pipe numbers are marked in the table.

The heavier walls of 0.280 inch could not be confirmed by the USCD wall thickness measurement. The 0.280 inch wall thickness is assigned to USCD features based on the linearly corrected distance.

All other USCD features are assigned 0.250 inch nominal wall thickness.

Based on the distance matching approach mentioned above, 14269 USCD features are assigned 0.250 inch wall thickness, 2 features for 0.375 inch wall thickness, and 9 features for 0.280 inch wall thickness. All the 11 heavier wall thickness features are ERW pipe, and are listed in Table 7. None of the USCD features locates in seamless pipes.



5. USCD REPORTED FEATURES

Crack-like and Crack-field features

The USCD tool can detect many forms of cracking and seam weld defects in pipelines. It reports indications as 'crack fields', which can be characteristic of Stress Corrosion Cracking (SCC), and reports 'crack-like' features, which are usually associated with lack of fusion defects, hook cracks, and fatigue cracks. Table 4 provides details of the crack field and crack-like features reported by the USCD tool. The features are reported as defects in base material (bm), adjoining the weld (aw), in the longitudinal weld (iw), or in not-decidable locations. It is conceivable that those defects reported as adjoining the seam weld may be associated with defects in the Heat Affected Zone (HAZ), i.e., hook cracks.

The USCD inspection detected 11 crack-like features in the base material where the seam weld orientation was unclear, as listed in Table 5. One of these features was excavated and it was confirmed that this feature was located in the weld. A reanalysis of the data for the other features could not decide whether the features were associated with the weld. Consequently, the other 10 features have been conservatively assessed using weld toughness as though they were located in the weld. Therefore, these 10 features have been counted in Table 4 as if they are in weld.

The 102 inspected ILI features from the 41 dig reports are excluded from the assessment. Instead, the indications and dimensions recorded in-field have been used to assess the significance of the features; the details are given in section 6.2. Of these 102 features, 77 crack-like and notch-like features are shown in detail in Table 4 as those of "verified in field". The other 25 not-decidable type features are not included in the table.

The crack-like and crack-field features were re-analyzed and sized. On this basis 244 features in the base metal, 3362 features adjoining the weld, 402 features in the weld, and 3 with location not-decidable (nd) have been reported. Included in these features are 55 features (7 bm, 46 aw, 2 iw) which were verified with field measurements. Since all the field indications have been assessed separately, these 55 features have been excluded from the assessment.

Since heavier wall pipe features are different material, and the fracture toughness data is unavailable, 2 crack-like features located in the heavier wall pipes have been excluded from the FAD assessment. These 2 features will be discussed separately. Consequently, 3954 crack-like features (237 bm, 3315 aw, 399 iw, 3 nd) have been assessed in this report by FAD level II method, based on USCD reported sizes.



Notch-like features

In the application of USCD technology, the probability that a notch-like features to be a crack is very low. Therefore, notch-like USCD features are usually not sized as part of the analysis process. However, the GE-IS inspection reports have shown that in this pipeline notch-like features may still possibly be associated with lack of fusion or crack defects. Since the possibility can not be confirmed without field inspection, all of the notches have been assessed by crack assessment method for safety.

Although notch-like features are sized and assessed by crack assessment method, the probability of a notch-like to be a crack is much lower than a crack-like feature. Therefore, the notch-like features can be remedied in a lower priority.

The notch-like features were re-analyzed and sized. On this basis 326 features in the base metal, 9912 features adjoining the weld, 92 features in the weld, and 16 with location not-decidable (nd) have been reported. Among these, 22 (20 aw, 2 iw) features were verified with field measurements. Since all the field indications have been assessed separately, these 22 features have been excluded from the assessment.

Since fracture toughness data for heavier wall pipe features is unavailable, 9 notch-like features cannot be assessed by FAD method, and have been considered separately. Consequently, 10315 notch-like features (325 bm, 9884 aw, 90 iw, 16 nd) have been assessed in this report, based on USCD reported sizes. Details in are shown in Table 4.

Summary

On the above basis, 570 features are reported in base material, 13274 features are reported adjoining weld, and 494 features in weld and 19 features in not-decidable location. Excluding the features that have been verified in the field and the heavier wall features, 562 bm features, 13199 aw features, 489 iw features, and 19 location not-decidable features are assessed based on USCD reported sizes. The numbers are listed in Table 4.



6. FEATURES ASSESSMENT

6.1 Assessment of USCD Features

Crack-like features adjoining seam weld (aw).

Excluding those features that have been repaired and excavated (section 3) and the heavier wall features, 3315 (3362-44-2-1) "aw" crack-like features were assessed by FAD method, based upon the USCD reported dimensions. The depth of one of these features (feature 0040-00553, joint 3645) is greater than 40% wall thickness. Therefore, this feature is considered unacceptable. The other 3314 aw crack-like features are assessed by the API 579 FAD Level II at MOP 1440 psi. Figure 3 shows the results of the assessment, and highlights that 173 features are unacceptable. All these 174 unacceptable features are listed in distance order in Table 8.

Crack-like features in seam weld (iw) and in not-decidable location (nd).

The 10 "bm" crack-like and notch-like features with unclear seam weld have been assessed assuming they are in the weld. On this basis and excluding the heavier wall features, 399 (402-2-1) iw and 3 nd crack-like features are assessed according to API 579 FAD Level II; 16 of these features are unacceptable at the MOP (1440 psi) as shown in Figure 4. These features are also included in Table 8.

Crack-like features in base materials (bm).

A total of 237 (244-5-2) crack-like features have been assessed by FAD level II method as "bm" features according to API 579 FAD Level II at the MOP (1440 psi). All the features are acceptable. Figure 5 shows the result of the FAD level II assessment.

Notch-like features adjoining seam weld (aw)

With the heavier wall features excluded, the integrity evaluation of the 9884 (9912-20-8) "aw" notch-like features was conducted by the FAD level II method based on the dimensions as reported by the USCD inspection. Figure 6 shows the API 579 FAD Level II assessment of the features at the MOP (1440 psi) and highlights that 26 features are unacceptable. These 26 features are included in Table 8.

Notch-like features in seam weld (iw) and in not-decidable (nd) location

90 (92-2) iw notch-like features and 16 nd notch-like features, totally 106 notch-like features, were assessed as assuming that they are all located in the weld. According to the API 579 FAD level II, all of these features are acceptable at the MOP 1440 psi, as shown in Figure 7.

Notch-like features in base materials (bm)

The 325 (326-1) bm notch-like features were assessed according to API 579 FAD level II, and all are acceptable at the MOP 1440 psi, as shown in Figure 8.



Heavier wall features

Based on the sheet of nominal wall thickness [9], the heavier wall pipes are X 35 grade steel. The fracture toughness data for these materials is unavailable, so the critical fracture toughness is estimated for the 11 features based on FAD level II method. The fracture toughness is then converted to or Charpy V-Notch based on Rolfe-Novak Correlation [3]:

$$K_{IC} = 9.35 (CVN)^{0.63} \quad (\text{ksi} \sqrt{\text{in}}, \text{ft-lb})$$

The following data have been used in this estimation.

Yield strength: 35 ksi; tensile strength 60 ksi; based on API 5L specification.

Outside diameter: 12.75 inch; MOP: 1440 psi.

Then, Dixie Pipeline Company can check the pipeline record or perform tests of the toughness or CVN for these heavier pipes, respectively for locations in base material, adjoining weld and in weld. If the actual data is greater than the critical toughness or CVN for each feature, then the feature is acceptable. Otherwise, it is unacceptable based on the FAD level II assessment, and investigation is then recommended.

6.2 Assessment of Field Indications

Crack assessment

The excavation program found 180 cracks, 168 lack of fusions. Features with measured sizes less than the USCD tool specification of sizing threshold (length 1 inch, depth 0.04 inch) have been excluded. All USCD features chosen for investigation were manually inspected in the field. However, some of the areas were then selected with instruction from Dixie Pipeline Company's engineer, and were re-inspected by PAUT technology. It has been recognized [10] that the PAUT inspection provided total defect depths, lengths, interlinking lengths, orientations, and more accurate measurement. Therefore, the defect indications reported by manual inspection in these selected areas are excluded from the assessment. Instead, the indications reported by PAUT inspection are assessed in this report. On the above basis, 163 field indications of crack and 129 lack of fusion defects have been assessed in this report.

Weld lack of fusion can be a planar defect, and therefore as a conservative manner, has to be assessed by crack assessment method, the API 579 FAD level II method. All indications of "lack of fusion and crack" and "crack and laminations" have been conservatively assessed as cracks by the same method. These indications have been assessed according to their dimensions measured in field (Table 9).

On the above basis, cracks and lack of fusions are assessed using the API 579 FAD level II approach. The results are shown in Figure 9 and Figure 10, respectively. It is highlighted that 11 features (9 cracks and 2 lack of fusions) are unacceptable and need to be repaired, which



are listed in Table 10. The assessment also includes features in joint 6903, which has been required for remediation on the basis of the site excavation reports.

Lamination assessment

The excavation program also found 3 linear laminations and 140 volumetric laminations when features with measured sizes less than the USCD tool sizing threshold (length 1 inch, depth 0.04 inch) have been excluded. Linear laminations are laminations that can interact with other defects, such as cracks, lack of fusion, or inclusions, and can potentially be surface breaking^[10]. The field inspections confirmed that all these 3 linear laminations are parallel to the outside surface. Volumetric laminations are parallel to the pipe surface and will not experience any through thickness loading^[10]. Therefore, these 143 laminations have been assessed by the API 579 lamination method^[3].

API 579 lamination assessment method specifies that if the pipeline is not operating in a hydrogen charging service, and if the distance of a lamination is greater than $1.8\sqrt{Dt}$ (inch) from a major structural discontinuity³ where D is the inside diameter, and t is the wall thickness, then the lamination is acceptable. Since the pipeline transmits propane, it is considered not operating in hydrogen charging conditions. The assessment of the 143 laminations confirmed that 142 were acceptable and that the lamination (Joint 329, feature ID 138) needs to be repaired if it is close to a major structural discontinuity between 16371.19 and 16372.03 feet. It is recommended that Dixie review their pipeline records to confirm the location of this lamination and determine whether it is associated with a major structural discontinuity, and make a repair decision on this basis.

In case hydrogen charging is observed in the pipeline or in the future the pipeline will change to hydrogen charging conditions, the laminations need to be re-assessed.

Other field indications

The field excavation program^[6] also found indications of "Mid-Wall Inclusions", "Roller/Tool Mark", "Score", "Scarfing Tool Marks", "Tool Mark", "ID Surface Tool Mark", "Int. Misalignment" and "Internal Inclusions". These indications have originated during the manufacturing process and have survived a number of hydrostatic tests. Consequently these anomalies do not pose a threat to the integrity of the pipeline.

The field excavation program also found indications of "Int. Metal Loss", "Corrosion", and "Dents". The assessment of these anomalies is beyond the scope of this report.

Please refer to field dig reports^[6] for the definitions of these anomalies.

³ Major Structural Discontinuity is a source of stress or strain intensification, which affects a relatively large portion of a structure and has a significant effect on the overall stress or strain pattern of the structure as a whole. Examples are head-to-shell and flange-to-shell junctions, nozzles, and junctions between shells of different diameters or thicknesses. Please see API 579 for details^[3].



6.3 Summary of Assessment for All Features

Table 11 summarizes the numbers of the USCD features and field inspections, which includes 216 unacceptable USCD features (190 crack-like features and 26 notch-like features) and 11 unacceptable field indications. In total, 3954 crack-like features, 10315 notch-like features, and 292 field indications have been assessed.

Prioritization of excavations is essential to ensure safe and cost-effective operation of a pipeline and to develop an integrity management strategy. The unacceptable USCD features have therefore been ranked based on the value of $L_r^2+K_r^2$ from the assessment. The interaction with other defects, the location of defects, and high consequence areas, should also be used to prioritize the investigations. In addition, a detailed excavation protocol is necessary to maximize data collection and to ensure the accuracy of field non-destructive evaluation sizing.

Table 12 provides details of the 216 unacceptable USCD features in ranking order, based on the value of $L_r^2+K_r^2$ from the assessment. The rankings are also included in Table 8 for the 216 USCD features. Excavation of these features is recommended.

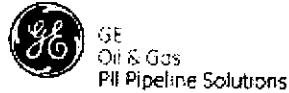
The 11 unacceptable field indications are also ranked by the same method, shown in Table 10. These indications are recommended for repair.

The notch-like features are also ranked by the same method. Since the probability of a notch-like feature to be a crack is low, the notch-like feature can either be considered in lower priority to all other crack-like features, or be treated based on the rankings.

The maximum unacceptable toughness or CVN for the 11 heavier wall USCD features have been decided. It has been recommended to check pipeline record or perform toughness or CVN test and decide the acceptability for the heavier wall features. If actual data is greater than the estimated data, then it is acceptable.

Investigations also need to be conducted to determine if one lamination is associated with a major structural discontinuity.

It is highlighted that some of these critical features may have been repaired after the 2005 excavation program. However, details of the repairs that have been conducted are not available and consequently it has not been possible to exclude these repaired features.



7. REMAINING LIFE OF SUB-CRITICAL INDICATIONS

The above assessment has shown that 3764 (237+3141+386) USCD crack-like features, 10289 (325+9858+106) USCD notch-like features and 281 (154+127) field indications, are acceptable at a pressure of 1440 psi. Because significant pressure cycling levels occur between Hattiesburg and Demopolis stations, the remaining fatigue life of these features has been calculated. The remaining life assessment for laminations is not required by API 579.

Dixie has provided operational pressure fluctuations taken at the discharge sections of Hattiesburg and Carmichael pump stations. These correspond to the pressures occurring between April 2004 and March 2005. It is highlighted that there were sections of the data where the information was not recorded. In addition, following discussions with Dixie, it was concluded that some pressure data were erroneous and were therefore excluded from the assessment. In the absence of further information, these operational cyclic pressures are assumed to be representative of future operational conditions.

The discharge pressure data at Hattiesburg and Carmichael pump station were converted into representative pressure histograms or blocks utilizing the RainFlow counting method, which is fully described in the Appendix. Figure 11 shows the pressure blocks produced by the RainFlow analysis for the Hattiesburg and Carmichael cyclic pressure data respectively. When comparing the resulting pressure ranges for Hattiesburg and Carmichael discharge pressure data, the Carmichael data contains a larger number of cycles at the high-pressure ranges (higher than 900 psi) than Hattiesburg.

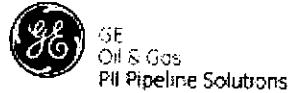
The representative pressure blocks obtained from the RainFlow analysis were utilized to determine the remaining fatigue life of all of sub critical indications. The fatigue life was computed by numerically integrating the Paris-Erdogan fatigue crack growth relation presented below:

$$\frac{da}{dN} = C\Delta K^m \quad (1)$$

$$N = \int_{ai}^{af} \frac{1}{C\Delta K^m} da \quad (2)$$

where:

- da/dN is the fatigue crack growth rate (in/cycle)
- C & m are fatigue crack growth parameters



- ΔK = cyclic stress intensity factor as a function of local stress, crack shape and instantaneous depth

The values of $C = 3.6 \times 10^{-10}$ and $m = 3.0$ employed throughout the assessment correspond to the upper bound crack growth rate applicable to ferritic-pearlite steels in air at room temperature. These values are both in fatigue handbooks and API 579, which are commonly used in the industry [3, 11].

The cyclic stress intensity factor (ΔK) for each sub-critical feature was calculated from the equivalent cyclic pressure range and the reported crack size, a_i . The total number of cycles to failure at the final crack size, a_f , as determined from the Level II FAD using lower bound material properties was then calculated, and converted to an equivalent number of years. Table 1 lists the material properties utilized during the determination of the fatigue life.

The remaining fatigue life of the 3764 sub-critical USCD crack-like features at the MOP was determined. 52 features become critical in 10 years, and totally 117 become critical in 20 years. Table 13 lists these features that grow to a critical size.

The remaining fatigue life of the 10289 sub-critical USCD notch-like features at the MOP was determined. 12 features become critical in 10 years and totally 24 become critical in 20 years. These features are listed in Table 13.

The remaining fatigue life of the 281 field-inspected sub-critical crack and lack of fusion defects at the MOP has also been determined. 3 field indications become critical within 10 years, and totally 6 become critical in 20 years. These features are listed in Table 14.

The remaining life of all the sub critical features is provided in a complete list of spreadsheet. The remaining life assessment method is based on Paris-Erdogan fatigue growth mechanism, which is most appropriate for seam weld feature. If significant changes to the operation condition and cyclic pressure are identified, the fatigue analysis should be repeated.



8. PIPELINE INTEGRITY MANAGEMENT STRATEGY

The integrity management strategy to ensure safe and cost-effective operation is discussed in this section.

Re-inspection interval

The integrity management strategy of this pipeline has been evaluated with respect to the required number of excavations over time. In an engineering and economical sense, features can be inspected during the same excavation if they are close each other. Therefore, 374 features, including all 227 critical features and 141 (117+24) USCD sub-critical features and 6 sub-critical field indication with 20 years remaining life, have been considered in the excavation program.

In terms of excavation, features in the same pipe joint are considered in the same excavation. In addition, if two features are in adjoining pipe joints and if the distance between them is less than 40 feet, they are also considered in the same excavation. The numbers of excavations in the follow years are obtained by an analysis of all these 374 features with this method. Table 15 shows the cumulative and additional number of excavations in 20 years. The numbers of cumulative excavations to be conducted in the following years are also illustrated in Figure 12.

In terms of engineering assessment, a re-inspection interval is acceptable as long as all critical features and sub critical features of a certain excavation year are excavated and remedied. Dixie Pipeline Company can decide the re-inspection interval based on Table 15 and Figure 12, depending on the costs and number of excavations.

The integrity strategy can be managed based on all the critical features and sub critical features with remaining life less than 20 years. These 374 features are listed in Table 16 in distance order, and can serve as the excavation plan. All 216 unacceptable USCD features are ranked based on the value of $L_r^2 + K_r^2$. The 11 field verified features are ranked separately from the other USCD unacceptable features, because they have been inspected in field by more accurate NDE technology. Again as discussed in Section 6, notch-like features are ranked based on feature assessment. Since the chance of these features to be crack is low, they can either be considered in lower priority to the crack-like features, or be considered based on the assessment rankings.

Features in the same pipe joint, or closer than 40 feet to each other, are highlighted. Although it is unlikely that the re-inspection interval will be longer than 10 years, it is an option for Dixie to inspect the sub-critical features with remaining life between 10 and 20 years. Dixie Pipeline Company needs to go through this list to verify whether it is appropriate in terms of excavation cost to box features in the same joint or closer than 40 feet, and then determine the final excavation plan.



Since the pipeline operation and environment conditions can vary with time the data collected during on-going excavation can be used to determine if the re-inspection interval needs to be revised.

Re-inspection method

Periodic hydrostatic test is an option to ensure the integrity of the pipeline by validating that all potential defects are below a specific size. However, following a hydrostatic test, sub-critical defects will still remain in the pipeline and, potentially, may be just smaller than the size that would have failed in the hydrostatic test. This pipeline contains a significant number of seam weld features; high-pressure tests may not be practicable in this case because the testing could potentially fail large numbers of weld flaws.

In addition, the hydrostatic test does not provide information about the number, location or severity of sub critical flaws.

In line inspection provides quantitative information on the flaw location and dimensions. The USCD data can be used to determine the characteristics and dimensions of crack like features but cannot easily differentiate laminations and cracks. It is highlighted that the UltraScan Wall Measurement (USWM) tool can reliably detect and characterise laminations.

Summary

As a pipeline integrity strategy for the next re-inspection, it is suggested that the pipeline be re-inspected with an ILI tool or be hydrostatically tested. Dixie Pipeline Company should determine the re-inspection interval based on Table 15 and Figure 12, depending on the costs and number of joints to be investigated. The defect sizes measured in ongoing excavations can be used to adjust the re-inspection interval.



9. CONCLUSIONS AND RECOMMENDATIONS

Dixie Pipeline Company operates a 12-inch diameter pipeline, which transports propane from Hattiesburg to Demopolis. The pipeline was constructed from API 5L Grade X52 Electric Resistance Welded (ERW) pre-1970 line pipe. During a re-qualification hydrostatic test program carried out in 1984 between Hattiesburg and Demopolis pump stations, a number of seam weld related failures occurred. This pipeline segment has therefore been identified as at risk from seam weld defects. As part of an ongoing integrity program, Dixie contracted GE to conduct a seam weld inspection utilizing the UltraScan™ Crack Detection (USCD) tool.

This report describes the findings of the re-assessment of the 2005 USCD data on the basis of the excavation findings and determines:

- The significance of USCD reported features and field defects at the MOP of 1440 psi;
- The effects of fatigue loading on the assessed defects; and
- A remediation and monitoring program.

Based on the preliminary Engineering Critical Assessment, Dixie excavated 41 sites to determine the sizes and characteristics of the features reported by the USCD inspection to allow a more accurate re-assessment. The excavation program confirmed that:

- features reported as mill trim tracks, surface breaking laminations or probable weld defects could be associated with crack or lack of fusion;
- notch-like USCD calls could be associated with cracks, or lack of fusion.

On the basis of the field data, all notch-like features have been sized and assessed as cracks. Crack-like features with comments of "mill trim tracks", "surface breaking laminations", or "probable weld defects" are assessed by crack assessment method. Other field findings are described in appendix.

In addition, all in-weld features have been sized. After the re-analysis of the USCD data of crack-like or notch-like, 570 features in the base metal, 13274 features adjoining the weld, 494 features in the weld, and 19 features in 'not-decidable' locations, were reported and sized. The assessment of the excavated ILI features has been replaced by that of the field indications, which provided more complete and accurate measurement.

Upon Dixie Pipeline engineer's request, the nominal wall thickness has been used in the assessment to replace the USCD tool measured wall thickness. The footage of nominal wall thickness from data sheet provided by Dixie has been linearly corrected to correlate with the USCD inspection distance. The nominal wall thickness data is then assigned to the USCD features. It has been found that 11 features are located in heavier wall pipes. None of the USCD features is located in seamless pipe. Since the toughness of heavier wall pipe is unavailable, these 11 features have been considered separately. The remaining USCD crack-like and notch-like features are assessed based on the USCD reported sizes by the FAD level II approach.



On the basis of the data collected in field, 163 cracks, and 129 lack of fusion defects have been assessed as cracks using the FAD level II approach. 143 laminations have been assessed according to the API 579 lamination assessment methodology.

The numbers of features unacceptable at the MOP (1440 psi) are shown in the following table, and have been ranked, based on feature severities.

	Number of unacceptable features
Crack-like features adjoining weld (aw)	174
Crack-like features in weld (iw)	16
Notch-like features adjoining weld (aw)	26
Crack found in field	9
Lack of fusion found in field	2
Total	227

It is recommended in priority order that Dixie:

- repair the 9 cracks, and 2 lack of fusion defects, which have been assessed as unacceptable on the basis of the 2005 excavation program;
- investigate the 174 adjoining weld crack-like (cl) features, 16 in weld cl features, 26 adjoining weld notch-like features that are unacceptable at the MOP 1440 psi;
- check alignment data for the lamination (Joint 329, feature ID 138) at a distance of 16371.19 to 16372.03 ft and repair if it is associated with a major structural discontinuity;
- check pipeline record or perform toughness or CVN test for heavier wall pipe, and then decide whether the 11 heavier wall USCD features are acceptable.

A fatigue analysis was conducted using standard fracture mechanics approach with the pressure cycling data supplied by Dixie, and simplified Rainflow Counting Methods. An excavation plan has been prepared for the unacceptable features and sub-critical features which are predicted to grow to an unacceptable size. Features in the same pipe joint or closer than 40 feet in adjoining pipe joints are considered in one excavation. The unacceptable features are ranked based on their severity to optimize the excavation program. The numbers of cumulative excavations in the following years are provided.

The pipeline should be re-inspected with an ILI tool or hydrostatically tested. Dixie Pipeline Company can select the appropriate re-inspection interval based on the costs and number of excavations. Data from ongoing excavations can be used to determine whether the re-assessment interval needs to be revised. If significant changes to the operating conditions and cyclic pressure are identified, the fatigue analysis should be repeated.



10. REFERENCES

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- [10] Internal communication with GEIS field staff who performed the site excavations.
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The authors acknowledge the help of discussions with Harold Kleeman and Kevin Spencer.



11. TABLES

Table 1: Mechanical Properties Used for the Assessment

Yield Strength (SMYS)	52.0	Ksi
Tensile Strength (minimum per API 5L)	66.0	Ksi
Young's Modulus (E)	30,000	Ksi
Conditional fracture toughness K_c at the Seam Weld (K_{JMAT}) ⁴	<u>54.7, 59.5, 61.2</u>	ksi/in
Conditional fracture toughness K_c adjoining the Seam Weld (K_{JMAT}) (0.25 inch from bond line) ⁵	<u>58.2, 70.8, 58.7</u>	ksi/in
Conditional fracture toughness K_c in Base Material (K_{JMAT}) ⁶	<u>111, 114, 159</u>	ksi/in

⁴ Fracture toughness measured from seam weld will be used to assess feature in the weld as type "iw".

⁵ Fracture toughness measured from heat-affected zone will be used to assess feature adjoining the weld as type "aw".

⁶ Fracture toughness measured from base material will be used to assess feature in pipe body as type "bm".



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Table 2: List of ILI features inspected during excavations. LOF: lack of fusion. Dig findings in this table are based on manual inspection only. Heading abbreviations are detailed in appendix. (1 of 2)

No.	Area No.	Pipe Joint No.	LW. ["]	Wt. [mil]	DugW [ft]	DgW [ft]	Distance [ft]	Deg ["]	Length [in]	Est Depth [%WT]	Rel. Pos.	Rad. Pos.	Type	Dig #	Dig finding	
1	02-00184	148	236.2	3.81	33.10	6800.92	336	9.30	25-40	bm	e	cl	1		cracks	
2	02-00348	175	279	236.2	11.35	46.95	8199.83	283	3.60	25-40	aw	e	cl	2		lack of fusion
3	02-00365	177	195	236.2	45.10	12.77	8350.58	197	2.00	25-40	aw	e	cl	3		lack of fusion
4	02-00647	179	28	236.2	43.36	12.81	8441.98	202	17.60	<12.5	bm	e	cl	4		corrosion
5	02-00494	193	125	236.2	49.99	9.06	9127.19	126	2.00	25-40	aw	e	cl	5		lack of fusion
6	03-00511	241	21	236.2	1.50	56.64	11629.12	22	3.10		aw	e	nl	6		lack of fusion
7	03-00521	241	21	236.2	14.16	43.98	11641.78	23	1.60		aw	nd	nl	6		lack of fusion
8	03-00547	241	21	236.2	38.64	19.50	11666.26	25	1.90	12.5-25	aw	e	cl	6		hook cracks
9	03-00550	241	21	236.2	39.97	18.17	11667.59	24	9.20	>40	aw	e	cl	6		hook cracks
10	03-00567	241	21	236.2	56.72	1.42	11684.34	24	0.80	12.5-25	aw	e	cl	6		hook cracks
11	03-01059	273	322	246.1	53.69	4.94	13345.03	355	4.70	<12.5	bm	e	cf	7		internal inclusions
12	03-01060	273	322	246.1	54.60	4.03	13345.94	51	1.60	12.5-25	bm	e	cf	7		internal inclusions
13	03-01431	295	19	226.4	53.66	4.58	14585.32	22	1.80	12.5-25	aw	e	cl	8		hook cracks
14	03-01433	295	19	226.4	55.03	3.21	14586.69	20	3.10	25-40	aw	e	cl	8		hook cracks
15	03-01465	296	19	226.4	22.80	34.38	14612.70	24	1.60		iw	e	cl	8a		Int metal loss
16	03-01485	296	19	226.4	35.38	21.80	14625.28	24	2.20	25-40	aw	e	cl	8a		lack of fusion
17	04-01172	302	127	246.1	32.46	26.49	14968.39	121	6.20	12.5-25	aw	e	cl	9		cracks
18	04-01173	302	127	246.1	33.05	25.90	14968.98	253	5.30	<12.5	bm	e	cf	9		internal inclusions
19	04-00071	302	127	246.1	35.32	23.63	14971.25	126	2.90		aw	e	nl	9		lack of fusion
20	04-01286	324	327	246.1	3.72	37.36	16061.59	329	20.80	25-40	aw	e	cl	10		cracks, LOF
21	04-00408	324	327	246.1	6.58	34.50	16064.45	326	1.40		aw	e	nl	10		cracks, LOF
22	04-01292	324	327	246.1	8.44	32.64	16066.31	324	49.60	12.5-25	aw	e	cl	10		cracks, LOF
23	04-00464	329	259	246.1	7.04	51.66	16320.26	257	3.30		iw	e	cl	11		cracks, score
24	04-01293	329	259	246.1	21.92	36.78	16335.14	258	43.70	12.5-25	aw	e	cl	11		cracks, score
25	04-00490	329	259	246.1	45.74	12.96	16358.96	260	49.20	12.5-25	aw	e	cl	11		cracks, score
26	04-01216	329	259	246.1	50.73	7.97	16363.95	260	42.90	12.5-25	aw	e	cl	11		cracks
27	04-00501	329	259	246.1	54.46	4.24	16367.68	260	46.00	25-40	aw	e	cl	11		cracks
28	04-00520	332	51	246.1	20.19	38.14	16497.52	54	2.00		aw	e	nl	12		cracks
29	04-01219	332	51	246.1	49.75	8.58	16527.08	100	9.00	12.5-25	bm	e	cf	12		internal inclusions
30	04-01294	353	127	236.2	7.63	50.90	17644.11	130	73.50	12.5-25	aw	e	cl	13		cracks
31	04-01233	353	127	236.2	30.93	27.60	17667.41	134	25.40	25-40	aw	e	cl	13		cracks
32	08-00035	675	252	236.2	5.36	48.12	34921.17	257	4.70		aw	e	nd	14		lack of fusion
33	09-01213	761	155	226.4	2.06	56.24	39467.97	154	649.90	25-40	aw	e	cl	15		cracks
34	13-00947	1139	24	226.4	32.36	25.68	60492.66	18	8.90	25-40	aw	e	cl	16		cracks
35	14-01117	1243	246	246.1	1.78	55.80	66123.01	249	485.70	25-40	aw	e	cl	17		cracks
36	15-00116	1318	140	236.2	45.44	13.48	69478.12	142	3.60		aw	nd	nl	39		lack of fusion
37	16-01164	1415	217	236.2	0.71	57.98	74648.45	216	686.80	25-40	aw	e	cl	18		cracks, LOF
38	40-00941	3640	81	236.2	9.22	26.23	194539.77	84	6.30		aw	e	nl	19		Int lack of fusion
39	40-00477	3640	81	236.2	24.94	10.51	194555.49	83	7.90		aw	nd	nd	19		int misalignment
40	40-01002	3640	81	236.2	27.76	7.69	194558.31	84	8.20		aw	nd	nd	19		int misalignment
41	40-00495	3640	81	236.2	32.94	2.51	194563.49	78	9.80		aw	i	nl	19		int misalignment
42	44-00889	4077	161	236.2	45.96	12.33	216007.77	164	1.20	<12.5	iw	i	nl	20		lack of fusion
43	08-00484	5073	30	226.0	27.50	25.73	269147.50	38	7.70		aw	e	nd	21		cracks
44	09-00602	5162	91	236.0	30.00	26.42	274061.49	94	3.00		iw	e	nl	38		lack of fusion
45	10-00281	5204	43	236.0	8.95	38.02	276313.39	44	3.40	>40	aw	e	cl	22		lack of fusion
46	10-00282	5204	43	236.0	9.58	37.38	276314.02	43	2.00		aw	e	nl	22		lack of fusion
47	10-00283	5204	43	236.0	11.42	35.55	276315.86	46	2.00	12.5-25	aw	e	cl	22		lack of fusion
48	10-00285	5204	43	236.0	14.15	32.82	276318.59	44	1.40		aw	e	nl	22		lack of fusion
49	10-00287	5204	43	236.0	20.52	26.45	276324.96	44	10.20	25-40	aw	e	cl	22		lack of fusion
50	10-00289	5204	43	236.0	25.96	21.00	276330.40	45	1.80	25-40	aw	e	cl	22		lack of fusion
51	10-00290	5204	43	236.0	26.99	19.98	276331.43	45	3.40	25-40	aw	e	cl	22		lack of fusion
52	10-00291	5204	43	236.0	29.55	17.42	276333.99	46	1.60		aw	e	nl	22		lack of fusion
53	10-00298	5204	43	236.0	45.89	1.06	276350.33	44	1.60		aw	e	nl	22		lack of fusion



Table 2: List of ILL features inspected during excavations (2 of 2).

No.	Area No.	Pipe Joint No.	LW. [m]	Wt. [ml]	DugW [ft]	DdGW [ft]	Distance [ft]	Deg [°]	Length [in]	Est. Depth [%WT]	Rel. Pos.	Rad. Pos.	Type	Dig #	Dig finding
54	11-00552	5326	315	236	19,429	38,174	283046.02	318	2.4	12.5-25	aw	e	cf	23	Sliver
55	21-00620	6262	54	236	2,564	55,972	333799.75	61	2.9	12.5-25	aw	e	cl	41	lack of fusion
56	22-00483	6265	265	236	2,598	55,751	333967.72	264	8.8	25-40	aw	e	cl	24	lack of fusion
57	22-00036	6265	265	236.0	46,12	12,23	334011.24	258	1.60		aw	e	nl	24	lack of fusion
58	22-00041	6266	342	236.0	27,88	30,33	334051.36	342	1.80		aw	e	ni	24a	lack of fusion
59	22-00042	6266	342	236	36,249	21,964	334059.72	342	8.1	<12.5	aw	e	cl	24a	lack of fusion
60	22-00047	6266	342	236.0	44,15	14,06	334067.62	344	2.40	25-40	aw	e	cl	24a	lamination
61	23-00633	6418	355	246	41,117	12,805	342444.53	354	52.4	25-40	aw	e	cl	40	cracks
62	24-00187	6468	121	236.0	7.76	44,23	345216.15	126	2.80	25-40	aw	e	cl	25	cracks, tool mark
63	24-00192	6468	121	236.0	14,88	37,11	345223.28	122	1.60		aw	e	nl	25	cracks
64	24-00204	6468	121	236.0	40,79	11,20	345249.19	124	3.30	>40	aw	e	cl	25	lack of fusion
65	24-00205	6468	121	236.0	41,30	10,69	345249.69	188	7.10	12.5-25	bm	i	cl	25	internal inclusions
66	24-00600	6511	53	246.0	23,40	34,68	347555.14	58	2.20	12.5-25	aw	e	cl	26	lack of fusion
67	24-00604	6511	53	246.0	28,81	29,27	347560.55	55	2.40	>40	aw	e	cl	26	Int lack of fusion
68	24-00743	6511	53	246.0	29,96	28,12	347561.70	55	4.10	25-40	aw	e	cl	26	Int lack of fusion
69	24-00605	6511	53	246.0	35,19	22,89	347566.93	56	1.20		aw	e	nl	26	lack of fusion
70	24-00607	6511	53	246.0	37,95	20,12	347569.70	55	2.20		aw	e	nl	26	Int lack of fusion
71	29-01168	6903	51	246	0.757	51,876	368987.49	53	66.7	25-40	aw	e	cl	27	lack of fusion
72	29-00117	6903	51	246	6,801	45,832	368993.53	54	44.4	25-40	aw	e	cl	27	Int lack of fusion
73	29-01169	6903	51	246	13,042	39,59	368999.78	52	73.4	25-40	aw	e	cl	27	Int lack of fusion
74	29-00130	6903	51	246	20,659	31,974	369007.39	54	15.9	12.5-25	aw	e	ci	27	lack of fusion
75	34-00980	7423	8	236.0	25,57	33,03	396998.13	9	3.50	25-40	aw	e	cl	28	lack of fusion
76	34-00982	7423	8	236.0	28,03	30,58	397000.59	9	10.10	25-40	aw	e	cl	28	lack of fusion/crack
77	34-00991	7423	8	236.0	46,22	12,39	397018.78	10	2.80	>40	aw	e	cl	28	lack of fusion
78	43-00550	8249	294	236.0	23,30	35,27	440094.46	295	4.70		aw	e	nd	29	lack of fusion
79	44-00021	8289	6	236.0	55,80	2,52	442307.35	8	5.00		aw	e	nd	30	lack of fusion
80	44-00692	8299	174	246.0	13,55	45,32	442820.56	176	6.30		aw	nd	nd	31	Int metal loss
81	45-00434	8429	81	236.0	2,14	36,92	450069.26	88	12.40		aw	i	nl	37	Roller/Tool Mark
82	45-00742	8429	81	236.0	31,93	7.14	450099.05	82	2.70		aw	e	nl	37	lack of fusion
83	45-00438	8429	81	236.0	34,28	4,79	450101.40	83	1.70		aw	e	nl	37	lack of fusion
84	47-00493	8596	66	246.0	6,39	51,94	459368.07	69	1.40	12.5-25	aw	e	cl	32	lack of fusion
85	47-00965	8596	66	246.0	54,09	4,25	459415.76	65	37.50		aw	e	nd	32	lack of fusion
86	52-00031	9015	158	236.0	29,40	29,33	481609.57	160	11.40		aw	e	nd	33	Int metal loss
87	70-00651	10737	68	246.0	5,07	53,09	572836.49	75	4.90		aw	e	nd	35	lack of fusion
88	70-00654	10737	68	246.0	6,66	51,50	572838.08	71	46.70		aw	e	nd	35	lack of fusion
89	70-00660	10737	68	246.0	12,99	45,17	572844.41	71	4.10		aw	e	nd	35	lack of fusion
90	70-00668	10737	68	246.0	17,57	40,59	572848.99	70	3.20		aw	e	nd	35	lack of fusion
91	70-00671	10737	68	246.0	19,60	38,56	572851.02	71	10.20		aw	e	nd	35	lack of fusion
92	70-00677	10737	68	246.0	22,68	35,48	572854.10	71	2.90		aw	e	nd	35	lack of fusion
93	70-00681	10737	68	246.0	25,17	32,99	572856.59	71	6.40		aw	e	nd	35	lack of fusion
94	70-00682	10737	68	246.0	26,31	31,86	572857.73	71	1.40		aw	e	nd	35	lack of fusion
95	70-00690	10737	68	246.0	35,40	22,76	572866.82	73	2.00		aw	e	nd	35	lack of fusion
96	70-00694	10737	68	246.0	38,02	20,14	572869.44	71	14.80		aw	e	nd	35	lack of fusion
97	70-00696	10737	68	246.0	39,89	18,28	572871.31	71	16.20		aw	e	nd	35	lack of fusion
98	70-00698	10737	68	246.0	42,61	15,55	572874.03	72	37.80		aw	e	nd	35	lack of fusion
99	70-00703	10737	68	246.0	46,56	11,60	572877.98	71	48.80		aw	e	nd	35	lack of fusion
100	70-00709	10737	68	246.0	51,87	6,29	572883.29	74	36.70		aw	e	nd	35	lack of fusion
101	70-00714	10737	68	246.0	55,06	3,11	572886.48	71	28.30		aw	e	nd	35	lack of fusion
102	83-00229	11896	41	236.0	28,15	31,05	634486.82	42	32.00		aw	e	nd	36	Int metal loss

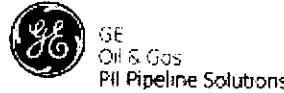


Table 3: Correlation of USCD features with field findings. Field indications by PAUT and manual inspection around USCD feature are counted.

	Crack-field, crack-like (59)			notch-like (22)			not-decidable (21)		
	Number	%	Number	%	Number	%	Number	%	
crack	549	66	16	30	6	6			
Lack of Fusion	119	14	32	59	57	61			
Lamination	106	13	4	7	27	29			
original manuf defect & metal loss	53	6	2	4	3	3			
Total	827	100	54	100	93	100			

Table 4: Summary of all USCD reported crack-like, crack-field and notch-like features.

Depth Group Range (% WT)	In Base Material (bm)			Adjoining the Seam Weld (aw)			in weld (iw)			Location not-decidable		Total
	Crack Field	Crack Like	Notch like	Crack Field	Crack Like	Notch like	Crack Field	Crack Like	Notch like	Crack Like	Notch like	
> 40	0	0	0	0	1	0	0	0	0	0	0	1
25 - 40	0	11	0	0	438	63	0	30	0	0	0	542
12.5 - 25	0	171	10	0	2051	1466	0	280	11	2	0	3991
< 12.5	0	55	316	0	826	8363	0	90	79	1	16	9746
Verified in field	5	2	0	2	44	20	0	2	2	0	0	77
Sub total	244	326		3362	9912		402	92	3	16		14357
Total	570			13274			494			19		14357
Sub total excluding field verified	237	326		3316	9892		400	90	3	16		14280
Total excluding field verified	563			13208			490			19		14280
Sub total excluding heavier wall features	237	325		3315	9884		399	90	3	16		14269
Total excluding heavier wall features	562			13199			489			19		14269

Because of unclear long seam orientation, 4 bm cl features have been counted as if iw cl, 6 bm nl features have been counted as if iw nl.

Table 5: List of features in base metal with unclear long seam weld orientation.

No.	Area No.	Pipe No.	LW. ["]	Wt. [mil]	DuGW [ft]	DdGW [ft]	Distance [ft]	Deg ["]	Length [in]	Width [in]	Est. Depth [%WT]	Rel. Pos.	Rad. Pos.	Type
DHD105	0002-00184	149	236	3.81	33.10	6800.92	336	9.3	0.8	25-40	bm	External	Crack-Like	
DHD105	0003-00864	262	246	32.34	25.99	12775.06	266	1.2	0.8	<12.5	bm	External	Notch-Like	
DHD105	0045-00020	4091	246	2.34	55.70	216724.03	194	74.2	1.3	12.5-25	bm	Internal	Crack-Like	
DHD205	0029-00151	6906	236	22.54	22.48	369122.47	213	1.6	0.6	<12.5	bm	External	Notch-Like	
DHD205	0029-00716	6952	226	22.27	34.08	371173.72	277	3.1	0.6	<12.5	bm	Internal	Notch-Like	
DHD205	0032-00683	7214	236	32.99	24.85	385647.82	381	9.9	0.6	<12.5	bm	Internal	Notch-Like	
DHD205	0051-00635	8950	236	41.12	17.52	478122.23	188	10.9	1.1	12.5-25	bm	Internal	Crack-Like	
DHD205	0053-00690	9196	246	0.39	54.26	491361.39	42	8	11.1	12.5-25	bm	External	Crack-Like	
DHD205	0071-00470	10842	246	44.37	13.78	578609.64	40	1.9	0.8	12.5-25	bm	External	Crack-Like	
DHD205	0076-00405	11304	236	39.50	19.26	603315.79	10	1.1	0.6	<12.5	bm	External	Notch-Like	
DHD205	0083-00174	11918	246	42.33	14.94	635157.88	321	1.5	0.6	<12.5	bm	External	Notch-Like	

Feature 0002-00184 at pipe no. 149 has been excavated and inspected in field. Therefore, it has been excluded from USCD feature assessment, and has been assessed based on field findings.



Table 6: Alignment of nominal wall thickness by calliper inspection with USCD distances and pipe numbers.

USCD Pipe No. Start	USCD Pipe No. End	Caliper Distance, ft	Linear Corrected (USCD) Distance, ft	Wall thickness, in	Pipe type	Note
		0.00	0.00	0.250	ERW	
15	25	442.00	439.44	0.375	ERW	
		658.00	654.19	0.250	ERW	
		1867.13	1856.32	0.280	Seamless	
		4232.48	4207.98	0.250	ERW	
841	848	44026.66	43771.77	0.375	Seamless	
		44294.43	44037.99	0.250	ERW	
1741	1742	92722.58	92185.78	0.375	ERW	
		92774.76	92237.65	0.250	ERW	
		167910.83	166938.73	0.280	ERW	Cannot confirm
		167972.87	167000.42	0.250	ERW	
		171602.36	170608.89	0.280	ERW	Cannot confirm
		171659.53	170665.73	0.250	ERW	
3833	3872	205367.13	204178.19	0.375	ERW	
		206058.56	204865.61	0.250	ERW	
4424	4434	235891.93	234526.27	0.375	Seamless	
		236221.16	234853.59	0.250	ERW	
4578	4586	243858.45	242446.67	0.375	ERW	
		244106.54	242693.32	0.250	ERW	
4768	4770	254011.95	252541.38	0.375	ERW	
		254061.94	252591.09	0.250	ERW	
5752	5758	308076.35	306292.79	0.375	Seamless	
		308113.93	306330.15	0.250	ERW	
6909	6912	371131.99	368983.38	0.375	ERW	
		371181.87	369032.97	0.250	ERW	
7518	7555	404282.11	401941.58	0.375	ERW	
		404972.13	402627.60	0.250	ERW	
8655	8657	464997.46	462305.42	0.375	ERW	
		465050.37	462358.03	0.250	ERW	
		520385.61	517372.91	0.280	ERW	Cannot confirm
		520430.80	517417.84	0.250	ERW	
10154	10241	545961.49	542800.73	0.375	ERW	
		549511.82	546330.50	0.250	ERW	
10443	10445	560481.24	557236.42	0.375	Seamless	
		560523.63	557278.56	0.250	ERW	
		570321.61	567019.82	0.280	ERW	Cannot confirm
		570381.85	567079.71	0.250	ERW	
11654	11657	625161.95	621542.67	0.375	Seamless	
		625255.79	621635.96	0.250	ERW	
11910	11915	638746.15	635048.22	0.375	ERW	
		638802.42	635104.17	0.250	ERW	
		639004.75	635305.33	0.375	Seamless	Cannot confirm



Table 7: List of USCD features matched heavier nominal wall thickness.

Area No.	Pipe No.	Wt. [mil]	DuGW [ft]	Distance [ft]	Length [in]	Est. Depth [%WT]	Rel. Pos.	Rad. Pos.	Type	Corrected Norm wt, in	Pipe type	Critical Toughness, ksi-in^0.5	Critical CVN, ft-lbs
0001-00199	24	344.0	9.01	755.9	2.2	<12.5	bm	e	nl	0.375	ERW	12.0	1.5
0034-00989	3124	236.0	43.32	166949.4	1.5	12.5-25	iw	i	cl	0.280	ERW	45.1	12.2
0035-01025	3195	236.0	0.67	170644.8	692.8	12.5-25	aw	e	cl	0.280	ERW	56.6	17.4
0035-00711	3195	236.0	2.59	170646.8	3.5	<12.5	aw	e	nl	0.280	ERW	21.4	3.7
0035-00719	3195	236.0	9.49	170653.6	1.2	<12.5	aw	i	nl	0.280	ERW	24.1	4.5
0042-00649	3858	364.0	16.29	204830.0	2.9	<12.5	aw	i	nl	0.375	ERW	14.2	1.9
0069-00295	10625	236.0	46.63	567025.8	2.0	<12.5	aw	i	nl	0.280	ERW	25.6	4.9
0069-00296	10625	236.0	47.85	567027.0	2.0	<12.5	aw	e	nl	0.280	ERW	20.3	3.4
0069-00975	10626	236.0	4.14	567041.7	1.4	<12.5	aw	e	nl	0.280	ERW	19.7	3.3
0069-00303	10626	236.0	7.65	567045.2	1.9	<12.5	aw	e	nl	0.280	ERW	20.2	3.4
0069-00304	10626	236.0	20.24	567057.8	3.1	<12.5	aw	e	nl	0.280	ERW	21.2	3.7

$$K_{IC} = 9.35 (CVN)^{0.63} \quad (\text{ksi} \sqrt{\text{in}}, \text{ft-lbs})^{[3]}$$



Table 8: Unacceptable USCD crack-like and notch-like features are listed in distance order. Ranking is based only on features in this table. Heading abbreviations are detailed in appendix. Assessment is based on level II FAD at MOP 1440 psi.

No.	Area No.	Pipe No.	DuGW [ft]	Distance [ft]	Length [in]	Est. Depth [%WT]	Rel. Pos.	Rad. Pos.	Type	Lr	Kr	Ranking
1	0003-01589	278	10.81	13592.0	49.80	25-40	aw	e	cl	1.033	0.680	93
2	0004-01350	355	44.24	17798.0	50.30	25-40	aw	e	cl	1.033	0.680	92
3	0004-00804	357	27.41	17885.6	6.90	25-40	aw	e	cl	0.994	0.648	169
4	0004-01006	379	25.40	19075.5	136.10	25-40	aw	e	cl	1.033	0.683	80
5	0004-01376	379	45.44	19095.5	32.00	25-40	aw	e	cl	1.034	0.677	98
6	0004-01261	381	47.65	19205.4	13.20	25-40	aw	e	nl	1.034	0.666	125
7	0004-01048	381	53.20	19210.9	6.00	25-40	aw	e	cl	0.977	0.643	185
8	0004-01265	382	32.29	19243.8	63.30	25-40	aw	e	cl	1.033	0.681	87
9	0004-01393	382	49.34	19260.9	7.90	25-40	aw	e	cl	1.008	0.653	148
10	0004-01271	383	32.42	19299.8	15.10	25-40	aw	e	cl	1.034	0.668	122
11	0004-01274	386	37.55	19478.3	16.10	25-40	aw	nd	nl	1.100	0.704	7
12	0004-01281	390	0.66	19669.8	111.40	25-40	aw	e	cl	1.033	0.683	82
13	0005-01022	397	42.00	20063.3	10.30	25-40	aw	e	nl	1.032	0.660	135
14	0006-01009	567	19.88	28948.8	173.00	25-40	aw	e	cl	1.033	0.684	77
15	0007-00964	628	0.31	32311.9	434.00	25-40	aw	e	cl	1.033	0.685	58
16	0008-00463	742	45.59	38667.1	5.90	25-40	aw	e	cl	0.975	0.642	188
17	0009-01195	774	0.35	40205.3	566.80	25-40	aw	e	cl	1.033	0.685	43
18	0009-01212	779	2.52	40464.2	491.60	25-40	aw	e	cl	1.033	0.685	51
19	0016-00607	1433	52.65	75643.0	5.60	25-40	aw	e	cl	0.969	0.639	196
20	0016-01139	1479	13.85	78183.1	241.10	25-40	aw	e	cl	1.033	0.684	73
21	0016-01090	1487	20.58	78616.0	4.90	25-40	iw	e	cl	0.951	0.672	193
22	0017-00870	1527	4.12	80710.6	536.20	25-40	aw	e	cl	1.033	0.685	45
23	0017-00626	1556	9.95	82274.9	5.20	25-40	aw	e	cl	0.959	0.635	209
24	0018-01020	1613	0.77	85410.8	465.30	25-40	aw	e	cl	1.033	0.685	52
25	0018-00619	1639	9.06	86845.3	9.10	25-40	aw	i	cl	1.086	0.684	13
26	0019-00752	1757	13.95	93230.1	5.10	25-40	aw	e	cl	0.956	0.634	211
27	0020-01039	1826	0.28	96559.8	615.90	25-40	aw	e	cl	1.033	0.685	34
28	0020-01040	1829	12.19	96730.4	419.00	25-40	aw	e	cl	1.033	0.685	59
29	0020-01015	1835	31.55	97089.9	6.00	25-40	aw	e	cl	0.977	0.643	186
30	0022-00839	2028	34.35	107823.2	17.10	25-40	iw	e	cl	1.034	0.713	18
31	0023-00609	2083	25.58	110759.7	50.50	25-40	aw	e	cl	1.033	0.680	91
32	0023-00286	2083	32.64	110766.8	5.30	25-40	aw	e	cl	0.961	0.636	203
33	0023-00611	2099	9.33	111668.0	232.60	25-40	aw	e	cl	1.033	0.684	74
34	0024-00833	2146	5.28	114218.1	203.60	25-40	aw	e	cl	1.033	0.684	75
35	0024-00510	2193	34.65	116774.4	8.60	25-40	aw	e	cl	1.016	0.656	143
36	0024-00657	2201	0.44	117182.6	7.20	25-40	aw	e	cl	0.998	0.650	161
37	0024-00674	2201	29.22	117211.4	16.90	25-40	aw	e	cl	1.034	0.670	115
38	0024-00821	2216	57.39	118041.2	4.50	25-40	iw	e	cl	0.939	0.666	208
39	0025-00809	2226	17.77	118586.9	30.70	25-40	aw	e	cl	1.034	0.677	99
40	0026-00642	2341	29.64	125019.3	7.50	25-40	aw	e	cl	1.003	0.651	156
41	0027-01119	2405	8.15	128524.5	540.30	25-40	aw	e	cl	1.033	0.685	44
42	0027-00109	2405	49.24	128565.6	20.60	25-40	aw	e	cl	1.034	0.673	111
43	0027-00110	2406	5.95	128581.5	5.50	25-40	iw	e	cl	0.966	0.679	174
44	0028-00828	2508	0.95	133980.7	661.10	25-40	aw	e	cl	1.033	0.685	29
45	0028-00645	2555	17.80	136610.8	6.20	25-40	iw	e	cl	0.981	0.685	155
46	0030-01297	2681	0.38	142720.4	702.80	25-40	aw	e	cl	1.033	0.685	24
47	0030-00152	2686	52.06	143050.0	6.80	25-40	aw	i	cl	1.055	0.669	23
48	0030-00309	2696	57.13	143617.7	5.60	25-40	aw	nd	cl	1.030	0.657	138
49	0030-01025	2753	23.17	146769.7	6.00	25-40	aw	nd	cl	1.040	0.661	118
50	0030-01034	2753	32.32	146778.9	4.90	25-40	aw	nd	cl	1.011	0.647	151
51	0030-01041	2753	39.30	146785.9	12.40	25-40	aw	nd	cl	1.100	0.697	10
52	0030-01046	2753	42.32	146788.9	24.50	25-40	aw	nd	cl	1.101	0.713	4
53	0031-01196	2774	13.89	147913.0	367.20	25-40	aw	e	cl	1.033	0.685	63
54	0031-00096	2777	55.55	148094.5	21.60	25-40	aw	e	cl	1.034	0.673	107
55	0031-00130	2780	55.96	148264.0	30.30	25-40	aw	e	cl	1.034	0.677	100



No.	Area No.	Pipe No.	DuGW [ft]	Distance [ft]	Length [in]	Est. Depth [%WT]	Rel. Pos.	Rad. Pos.	Type	Lr	Kr	Ranking
56	0031-00297	2796	24.85	149107.6	107.80	25-40	aw	e	cl	1.033	0.683	83
57	0031-00303	2796	37.77	149120.5	28.20	25-40	aw	e	cl	1.034	0.676	102
58	0031-00312	2797	12.30	149146.4	40.30	25-40	aw	e	cl	1.034	0.679	96
59	0031-00322	2798	52.04	149244.0	54.10	25-40	aw	e	cl	1.033	0.681	90
60	0031-00928	2843	8.07	151542.3	11.20	25-40	aw	e	cl	1.034	0.662	130
61	0031-00959	2843	40.46	151574.7	10.00	25-40	aw	e	cl	1.030	0.660	136
62	0031-00971	2843	55.33	151589.5	7.90	25-40	aw	e	nl	1.008	0.653	149
63	0033-00120	2968	7.54	158409.5	8.40	25-40	aw	i	nl	1.079	0.681	14
64	0033-00127	2968	31.55	158433.5	7.00	25-40	aw	i	nl	1.059	0.671	20
65	0033-00367	3004	52.16	160490.1	6.30	25-40	aw	e	cl	0.983	0.645	178
66	0034-00279	3077	38.93	164424.7	4.10	25-40	aw	i	cl	0.985	0.632	183
67	0034-00339	3079	48.83	164548.8	116.60	25-40	aw	e	cl	1.033	0.683	81
68	0034-01059	3083	8.84	164736.9	200.30	25-40	aw	e	cl	1.033	0.684	76
69	0034-00446	3086	5.74	164910.4	321.10	25-40	aw	e	cl	1.033	0.684	68
70	0034-00952	3122	24.73	166813.1	6.00	25-40	aw	e	cl	0.977	0.643	187
71	0035-00131	3140	15.14	167706.0	26.80	25-40	aw	e	cl	1.034	0.676	103
72	0035-01008	3186	19.77	170179.6	25.20	25-40	aw	e	cl	1.034	0.675	105
73	0035-00599	3186	22.75	170182.6	24.30	25-40	aw	e	cl	1.034	0.675	106
74	0035-01023	3198	4.87	170824.1	526.70	25-40	aw	e	cl	1.033	0.685	46
75	0036-00962	3234	1.99	172724.7	437.30	25-40	aw	e	cl	1.033	0.685	57
76	0038-00405	3464	7.76	185031.1	14.20	25-40	aw	i	nl	1.100	0.701	9
77	0039-00458	3548	10.11	189549.0	7.20	25-40	aw	e	cl	0.998	0.650	162
78	0039-00777	3588	4.83	191748.4	6.40	25-40	aw	e	cl	0.985	0.645	177
79	0040-00352	3631	7.40	194041.1	20.80	25-40	aw	e	cl	1.034	0.673	109
80	0040-00553	3645	31.53	194819.1	3.10	>40	aw	e	cl			1
81	0040-00955	3645	49.95	194837.5	6.70	25-40	aw	e	cl	0.990	0.647	172
82	0040-00875	3681	10.13	196677.9	14.40	25-40	aw	e	cl	1.034	0.668	124
83	0041-00518	3756	8.45	200870.6	5.30	25-40	aw	e	cl	0.961	0.636	204
84	0042-01006	3885	1.67	205715.7	273.00	25-40	aw	e	cl	1.033	0.684	70
85	0042-01001	3897	5.90	206369.7	323.40	25-40	aw	e	cl	1.033	0.684	67
86	0043-01142	3905	0.80	206728.1	462.60	25-40	aw	e	cl	1.033	0.685	54
87	0043-00096	3915	37.31	207341.0	4.10	25-40	aw	nd	cl	0.985	0.632	184
88	0043-00447	3952	35.11	209419.2	9.50	25-40	aw	e	cl	1.025	0.658	141
89	0043-00723	3969	34.78	210363.2	7.20	25-40	aw	e	cl	0.998	0.650	163
90	0043-00858	3975	2.30	210619.0	5.10	25-40	aw	e	cl	0.956	0.634	212
91	0044-00278	4013	45.60	212784.3	8.30	25-40	aw	i	cl	1.077	0.680	15
92	0044-00572	4035	43.32	214037.3	18.80	25-40	aw	e	cl	1.034	0.672	113
93	0044-01047	4046	2.36	214601.8	6.30	25-40	aw	e	cl	0.983	0.645	179
94	0045-01421	4087	42.60	216558.5	20.10	25-40	aw	e	cl	1.034	0.673	112
95	0045-00527	4120	25.51	218348.4	7.30	25-40	aw	e	cl	1.000	0.650	159
96	0045-00537	4120	43.99	218366.9	16.00	25-40	aw	e	cl	1.034	0.669	120
97	0045-01438	4125	46.28	218658.2	12.50	25-40	aw	e	cl	1.034	0.665	126
98	0045-00798	4137	16.59	219284.1	11.20	25-40	aw	e	cl	1.034	0.662	131
99	0045-01315	4173	49.41	221277.1	21.20	25-40	aw	e	nl	1.034	0.673	108
100	0046-00116	4183	25.76	221800.7	4.40	25-40	iw	e	cl	0.935	0.665	210
101	0046-00426	4205	39.65	222977.6	5.40	25-40	aw	e	cl	0.964	0.637	200
102	0046-00598	4220	21.50	223833.9	8.40	25-40	aw	e	cl	1.014	0.655	145
103	0003-00194	4556	8.11	241641.4	12.30	25-40	aw	e	nl	1.034	0.664	127
104	0003-00693	4615	47.68	244487.2	5.50	25-40	aw	e	cl	0.966	0.638	197
105	0004-00471	4705	18.02	249355.1	8.80	25-40	aw	e	nl	1.019	0.656	142
106	0005-01008	4748	7.11	251772.0	398.90	25-40	aw	e	cl	1.033	0.685	61
107	0005-01011	4755	1.91	252154.9	648.50	25-40	aw	e	cl	1.033	0.685	31
108	0005-00699	4781	32.09	253300.0	5.50	25-40	iw	e	cl	0.966	0.679	175
109	0006-00639	4851	5.99	257100.4	613.00	25-40	aw	e	cl	1.033	0.685	36
110	0007-00633	4976	4.07	263870.2	594.20	25-40	aw	e	cl	1.033	0.685	40
111	0008-00126	5008	21.31	265606.7	5.90	25-40	aw	e	cl	1.033	0.704	22
112	0008-00530	5076	20.18	269308.8	10.80	25-40	iw	e	cl	1.034	0.685	60
113	0008-00589	5079	1.18	269457.1	412.20	25-40	aw	e	cl	1.033	0.685	38
114	0009-00741	5173	0.58	274610.3	606.70	25-40	aw	e	cl	1.033	0.685	



No.	Area No.	Pipe No.	DugW [ft]	Distance [ft]	Length [in]	Est. Depth [%WT]	Rel. Pos.	Rad. Pos.	Type	Lr	Kr	Ranking
115	0010-00021	5180	33.19	275027.0	7.70	25-40	aw	e	cl	1.006	0.652	152
116	0011-00128	5287	16.91	280875.9	74.40	25-40	aw	e	cl	1.033	0.682	85
117	0012-00684	5384	10.37	286318.9	16.90	25-40	aw	e	cl	1.034	0.670	116
118	0012-00161	5394	17.01	286909.5	7.10	25-40	aw	e	cl	0.997	0.649	166
119	0012-00612	5440	16.56	289371.4	29.50	25-40	aw	e	cl	1.034	0.677	101
120	0012-00638	5440	53.51	289408.3	46.90	25-40	aw	e	cl	1.033	0.680	94
121	0012-00675	5441	45.07	289457.3	5.30	25-40	aw	e	cl	0.961	0.636	205
122	0013-00542	5514	48.72	293412.1	5.10	25-40	aw	e	cl	0.956	0.634	213
123	0013-00652	5522	15.87	293845.5	4.00	25-40	aw	i	cl	0.981	0.630	192
124	0014-00345	5589	8.08	297509.7	17.00	25-40	aw	e	nl	1.034	0.670	114
125	0014-00419	5599	30.20	298116.0	5.10	25-40	aw	e	cl	0.956	0.634	214
126	0016-00054	5726	15.05	305160.6	357.70	25-40	aw	e	cl	1.033	0.685	64
127	0016-00739	5740	0.13	305935.3	336.60	25-40	aw	e	cl	1.033	0.685	66
128	0016-00731	5764	52.85	306770.0	12.00	25-40	aw	e	cl	1.034	0.664	128
129	0016-00359	5767	38.01	306910.4	6.20	25-40	aw	e	cl	0.981	0.644	182
130	0016-00735	5770	0.18	307043.5	676.00	25-40	aw	e	cl	1.033	0.685	25
131	0019-00536	6005	50.87	319920.2	32.20	25-40	iw	e	cl	1.034	0.721	17
132	0019-00376	6054	7.40	322583.8	509.10	25-40	aw	e	cl	1.033	0.685	48
133	0019-00561	6060	3.50	322925.5	578.40	25-40	aw	e	cl	1.033	0.685	41
134	0020-00609	6102	39.10	325078.6	16.70	25-40	aw	i	cl	1.100	0.705	6
135	0020-00119	6105	13.86	325213.1	3.60	25-40	aw	i	nl	0.970	0.620	207
136	0020-00169	6106	16.50	325271.9	15.00	25-40	aw	i	nl	1.100	0.702	8
137	0020-00623	6139	29.86	327134.9	83.30	25-40	aw	e	cl	1.033	0.685	84
138	0025-00041	6536	32.54	348825.0	3.70	25-40	aw	i	cl	0.973	0.623	201
139	0025-00754	6585	0.70	351547.2	675.90	25-40	aw	e	cl	1.033	0.685	26
140	0026-01048	6691	12.53	357387.8	463.20	25-40	aw	e	cl	1.033	0.685	53
141	0027-00906	6736	1.59	359936.9	569.20	25-40	aw	e	cl	1.033	0.685	42
142	0031-00944	7096	1.80	379099.8	15.30	25-40	aw	e	cl	1.034	0.669	121
143	0031-00912	7115	29.67	380119.2	9.80	25-40	aw	e	nl	1.028	0.659	139
144	0031-00689	7129	31.14	380929.5	6.90	25-40	aw	e	cl	0.994	0.648	170
145	0032-00056	7174	16.41	383438.4	5.70	25-40	aw	e	cl	0.971	0.640	194
146	0033-01048	7287	21.83	389678.5	20.70	25-40	aw	e	cl	1.034	0.673	110
147	0033-01077	7301	23.12	390453.4	24.90	25-40	aw	i	cl	1.101	0.713	3
148	0033-00900	7333	38.78	392261.1	6.30	25-40	aw	e	cl	0.983	0.645	180
149	0034-00974	7423	9.04	396981.6	16.90	25-40	aw	e	cl	1.034	0.670	117
150	0034-00995	7423	50.91	397023.5	5.90	25-40	aw	e	cl	0.975	0.642	190
151	0034-01048	7427	20.70	397227.9	11.00	25-40	aw	e	cl	1.034	0.662	133
152	0035-00798	7467	34.89	399384.6	9.20	25-40	aw	i	cl	1.088	0.685	12
153	0035-00821	7494	3.49	400837.8	606.70	25-40	aw	e	cl	1.033	0.685	39
154	0035-00555	7509	25.66	401714.3	6.90	25-40	aw	e	cl	0.994	0.648	171
155	0036-00008	7557	2.88	402825.6	8.50	25-40	aw	e	cl	1.015	0.655	144
156	0036-00553	7606	51.89	405579.2	70.00	25-40	aw	e	cl	1.033	0.682	86
157	0036-00855	7609	3.34	405704.9	9.90	25-40	aw	e	cl	1.029	0.659	137
158	0036-00705	7618	7.84	406213.9	5.10	25-40	aw	e	cl	0.956	0.634	215
159	0036-00804	7634	8.85	407088.5	26.00	25-40	aw	i	cl	1.101	0.714	2
160	0037-00654	7714	25.26	411550.4	39.30	25-40	aw	e	cl	1.034	0.679	97
161	0038-00190	7757	20.40	413933.4	8.10	25-40	aw	nd	cl	1.075	0.679	16
162	0038-00382	7781	16.70	415299.3	16.20	25-40	aw	e	cl	1.034	0.669	119
163	0038-00900	7823	12.84	417548.4	26.40	25-40	aw	e	cl	1.034	0.676	104
164	0039-00490	7859	17.63	419301.8	6.50	25-40	aw	e	nl	0.987	0.646	176
165	0039-00491	7859	22.52	419306.7	5.10	25-40	aw	e	nl	0.956	0.634	216
166	0041-00761	8023	2.69	427771.7	609.50	25-40	aw	e	cl	1.033	0.685	37
167	0041-00085	8028	6.22	428063.5	7.60	25-40	aw	e	cl	1.004	0.652	154
168	0041-00763	8035	3.76	428452.4	439.90	25-40	aw	e	cl	1.033	0.685	56
169	0041-00764	8036	13.20	428517.9	506.30	25-40	aw	e	cl	1.033	0.685	49
170	0041-00393	8064	21.90	429948.4	5.90	25-40	aw	e	cl	0.975	0.683	165
171	0041-00766	8072	4.26	430424.1	260.70	25-40	aw	e	cl	1.033	0.684	72
172	0041-00533	8076	14.37	430652.6	11.20	25-40	aw	e	cl	1.034	0.662	132
173	0041-00767	8084	2.32	431099.2	666.10	25-40	aw	e	cl	1.033	0.685	28



No.	Area No.	Pipe No.	DuGW [ft]	Distance [ft]	Length [in]	Est. Depth [%WT]	Rel. Pos.	Rad. Pos.	Type	Lr	Kr	Ranking
174	0041-00768	8092	18.30	431547.4	450.70	25-40	aw	e	cl	1.033	0.685	55
175	0043-00847	8200	1.94	437309.7	617.90	25-40	aw	e	cl	1.033	0.685	35
176	0044-00300	8328	7.37	444401.8	12.00	25-40	aw	e	nl	1.034	0.664	129
177	0045-00108	8381	0.60	447385.7	310.40	25-40	aw	e	cl	1.033	0.684	69
178	0045-00197	8398	26.98	448391.9	8.10	25-40	aw	e	cl	1.011	0.654	146
179	0045-00745	8405	0.51	448776.6	644.30	25-40	aw	e	cl	1.033	0.685	32
180	0045-00744	8438	3.74	450523.8	499.10	25-40	aw	e	cl	1.033	0.685	50
181	0046-00713	8491	30.55	453528.5	60.90	25-40	aw	e	nl	1.033	0.681	89
182	0048-00339	8677	23.14	463456.1	350.20	25-40	aw	e	cl	1.033	0.685	65
183	0049-00207	8769	27.53	468346.4	19.50	25-40	aw	i	nl	1.100	0.709	5
184	0051-00578	9006	34.96	481139.4	6.10	25-40	iw	e	cl	0.979	0.685	158
185	0052-00521	9091	5.45	485884.4	12.00	25-40	iw	e	cl	1.034	0.706	21
186	0053-00648	9190	19.77	491112.9	260.90	25-40	aw	e	cl	1.033	0.684	71
187	0055-00493	9371	6.88	500710.5	9.20	25-40	iw	e	cl	1.023	0.700	78
188	0056-00061	9391	28.79	501855.4	62.50	25-40	aw	e	cl	1.033	0.681	88
189	0056-00825	9444	25.91	504773.5	374.70	25-40	aw	e	cl	1.033	0.685	62
190	0056-00944	9451	10.72	505150.2	7.10	25-40	aw	e	cl	0.997	0.649	167
191	0056-01075	9464	48.29	505874.3	7.30	25-40	aw	e	cl	1.000	0.650	160
192	0058-00888	9564	8.93	511234.5	5.50	25-40	aw	e	nl	0.966	0.638	198
193	0059-00059	9654	25.92	516165.9	9.70	25-40	aw	e	nl	1.027	0.659	140
194	0059-00641	9683	38.99	517718.0	4.30	25-40	iw	i	cl	0.992	0.677	150
195	0060-00371	9775	45.75	522736.0	10.60	25-40	aw	i	nl	1.100	0.691	11
196	0062-00514	10004	51.80	535057.0	6.50	25-40	iw	e	cl	0.987	0.687	147
197	0064-00597	10110	8.34	540615.9	141.50	25-40	aw	e	cl	1.033	0.683	79
198	0064-00206	10136	45.69	542077.4	5.30	25-40	aw	e	nl	0.961	0.636	206
199	0065-00286	10270	45.47	547744.8	10.60	25-40	aw	e	cl	1.034	0.661	134
200	0066-00221	10345	4.15	551925.2	3.70	25-40	aw	i	cl	0.973	0.623	202
201	0067-00706	10450	0.48	557532.8	626.10	25-40	aw	e	cl	1.033	0.685	33
202	0068-00280	10552	39.24	562986.4	14.50	25-40	iw	e	cl	1.034	0.710	19
203	0068-00699	10557	1.20	563239.1	650.50	25-40	aw	e	cl	1.033	0.685	30
204	0071-00693	10824	42.33	577647.3	14.60	25-40	aw	e	cl	1.034	0.668	123
205	0072-00627	10931	6.36	583228.1	6.30	25-40	aw	e	cl	0.983	0.645	181
206	0072-00753	10944	0.83	583911.9	7.10	25-40	aw	e	nl	0.997	0.649	168
207	0073-00003	10965	33.42	584890.6	5.90	25-40	aw	e	nl	0.975	0.642	191
208	0073-00150	10986	46.13	586020.2	7.50	25-40	aw	e	nl	1.003	0.651	157
209	0074-01025	11137	1.96	594059.8	670.20	25-40	aw	e	cl	1.033	0.685	27
210	0075-00124	11180	13.64	596330.5	5.50	25-40	aw	e	cl	0.966	0.638	199
211	0077-01196	11360	7.63	606475.1	6.60	25-40	aw	e	cl	0.989	0.647	173
212	0079-00871	11526	1.06	614806.9	521.70	25-40	aw	e	cl	1.033	0.685	47
213	0081-00258	11748	26.52	626503.5	7.20	25-40	aw	e	cl	0.998	0.650	164
214	0082-00822	11829	15.76	630916.6	7.70	25-40	aw	e	cl	1.006	0.652	153
215	0082-00336	11829	27.17	630928.0	5.70	25-40	aw	e	cl	0.971	0.640	195
216	0082-00614	11869	47.49	633086.5	42.10	25-40	aw	e	cl	1.034	0.679	95

**Table 9: Number of field indications assessed in this report.**

Field indications	Number	Note
Crack	163	including indications of "lack of fusion and crack", "Crack and Lamination", "crack hook".
Lack of fusion	129	including internal, external, middle wall lack of fusion.
Linear lamination *	3	
Volumetric lamination *	140	including "lamination intermittent".
Total	435	

Indications with dimensions less than USCD sizing threshold (1 inch length, 0.04 inch depth) have been excluded. Other types of indications are not included in this table. Manual field measurements for Crack and Lack of fusion field indications that were selected for PAUT inspection, have been excluded from the numbers.

* assessed by API 579 lamination method.

Table 10: Field inspected cracks and lack of fusion that are unacceptable, based on level II FAD at MOP 1440 psi.

Joint #	Inspection type	Type	Feature ID	Absolute Distance	USGW (ft)	Rel. Pos.	Rad. Pos.	Length (in)	Max Depth (in)	Lr	Kr	Pass / Fail	Ranking
5204	PAUT	Crack	5	276313.33	8.89	AW	Ext	3.43	0.123	0.940	0.780	Fail	4
5204	PAUT	Lack of fusion & crack	52	276350.14	45.85	IW/AW	Ext	7.53	0.100	0.976	0.673	Fail	7
6903	PAUT	Crack	47	368987.52	0.79	AW	Ext	13.50	0.100	1.015	0.652	Fail	5
6903	PAUT	Crack	16	368994.70	7.97	AW	Ext	24.05	0.169	1.587	2.015	Fail	1
6903	PAUT	Crack	21	368996.71	9.98	AW	Ext	4.20	0.110	0.935	0.698	Fail	10
6903	PAUT	Crack	22	368997.09	10.36	AW	Ext	7.50	0.100	0.982	0.637	Fail	8
6903	PAUT	Crack	27	368999.23	12.49	IW	Ext	18.05	0.123	1.153	1.024	Fail	2
6903	PAUT	Crack	43	369004.70	17.96	AW	Ext	18.30	0.095	0.989	0.620	Fail	9
10737	PAUT	Lack of fusion ID/OD/MW Stacked	14	572837.78	6.36	IW	MW	3.70	0.120	0.989	0.778	Fail	3
10737	PAUT	Lack of fusion & crack	15	572839.39	7.97	IW	Int	23.08	0.090	1.002	0.643	Fail	6
10737	PAUT	Lack of Fusion	65	572873.40	41.98	IW	Ext	24.00	0.095	0.965	0.645	Fail	11

Remediation was required at Joint 6903 during the excavation program. Please refer to the Dixie Pipeline Companies Repair Documentation for repair type and location.

Manual field measurements for Crack and Lack of fusion field indications that were selected for PAUT inspection, have been excluded from the numbers.



Table 11: Numbers of acceptable / unacceptable features assessed by FAD level II method at MOP 1440 psi in this report.

	Acceptable	Unacceptable	Total
Crack-like features at base materials (bm)	237	0	237
Crack-like features adjoining weld (aw)	3141	174	3315
Crack-like features in weld (iw, nd)	386	16	402
Notch-like features at base materials (bm)	325	0	325
Notch-like features adjoining weld (aw)	9858	26	9884
Notch-like features in weld (iw)	106	0	106
Crack found in field	154	9	163
Lack of fusion found in field	127	2	129
Total	14334	227	14561

Field indications with dimensions less than USCD tool sizing threshold (1 inch length, 0.04 inch depth) have been excluded.

USCD features for field investigation are manually inspected by NDE technique. Some areas are selected for further PAUT inspection. The manual measurements of these selected areas are excluded in the above numbers.

11 heavier wall USCD features are not included in this table.

There are 143 laminations assessed by API 579 laminations assessment method, which is different from the FAD method. Therefore, this number is not included in this table.

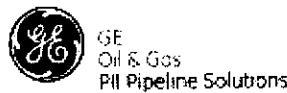


Table 12: List of all unacceptable USCD crack-like and notch-like features in ranking order. Assessment is based on level II FAD at MOP 1440 psi. Abbreviations are detailed in appendix.

Area No.	Pipe No.	DuGW [ft]	Distance, [ft]	Length [in]	Est. Depth [%WT]	Rel. Pos.	Rad. Pos.	Type	Lr	Kr	Ranking
0040-00553	3645	31.53	194819.1	3.10	>40	aw	e	cl			1
0036-00804	7634	8.85	407088.5	26.00	25-40	aw	i	cl	1.101	0.714	2
0033-01077	7301	23.12	390453.4	24.90	25-40	aw	i	cl	1.101	0.713	3
0030-01046	2753	42.32	146788.9	24.50	25-40	aw	nd	cl	1.101	0.713	4
0049-00207	8769	27.53	468346.4	19.50	25-40	aw	i	nl	1.100	0.709	5
0020-00609	6102	39.10	325078.6	16.70	25-40	aw	i	cl	1.100	0.705	6
0004-01274	386	37.55	19478.3	16.10	25-40	aw	nd	nl	1.100	0.704	7
0020-00169	6106	16.50	325271.9	15.00	25-40	aw	i	nl	1.100	0.702	8
0038-00405	3464	7.76	185031.1	14.20	25-40	aw	i	nl	1.100	0.701	9
0030-01041	2753	39.30	146785.9	12.40	25-40	aw	nd	cl	1.100	0.697	10
0060-00371	9775	45.75	522736.0	10.60	25-40	aw	i	nl	1.100	0.691	11
0035-00798	7467	34.89	399384.6	9.20	25-40	aw	i	cl	1.088	0.685	12
0018-00619	1639	9.06	86845.3	9.10	25-40	aw	i	cl	1.086	0.684	13
0033-00120	2968	7.54	158409.5	8.40	25-40	aw	i	nl	1.079	0.681	14
0044-00278	4013	45.60	212784.3	8.30	25-40	aw	i	cl	1.077	0.680	15
0038-00190	7757	20.40	413933.4	8.10	25-40	aw	nd	cl	1.075	0.679	16
0019-00536	6005	50.87	319920.2	32.20	25-40	iw	e	cl	1.034	0.721	17
0022-00839	2028	34.35	107823.2	17.10	25-40	iw	e	cl	1.034	0.713	18
0068-00280	10552	39.24	562986.4	14.50	25-40	iw	e	cl	1.034	0.710	19
0033-00127	2968	31.55	158433.5	7.00	25-40	ow	i	nl	1.059	0.671	20
0052-00521	9091	5.45	485884.4	12.00	25-40	iw	e	cl	1.034	0.706	21
0008-00530	5076	20.18	269308.8	10.80	25-40	iw	e	cl	1.034	0.704	22
0030-00152	2686	52.06	143050.0	6.80	25-40	aw	i	cl	1.055	0.669	23
0030-01297	2681	0.38	142720.4	702.80	25-40	aw	e	cl	1.033	0.685	24
0016-00735	5770	0.18	307043.5	676.00	25-40	aw	e	cl	1.033	0.685	25
0025-00754	6585	0.70	351547.2	675.90	25-40	aw	e	cl	1.033	0.685	26
0074-01025	11137	1.96	594059.8	670.20	25-40	ow	e	cl	1.033	0.685	27
0041-00767	8084	2.32	431099.2	666.10	25-40	ow	e	cl	1.033	0.685	28
0028-00828	2508	0.95	133980.7	661.10	25-40	ow	e	cl	1.033	0.685	29
0068-00699	10557	1.20	563239.1	650.50	25-40	ow	e	cl	1.033	0.685	30
0005-01011	4755	1.91	252154.9	648.50	25-40	ow	e	cl	1.033	0.685	31
0045-00745	8405	0.51	448776.6	644.30	25-40	aw	e	cl	1.033	0.685	32
0067-00706	10450	0.48	557532.8	626.10	25-40	aw	e	cl	1.033	0.685	33
0020-01039	1826	0.28	96559.8	615.90	25-40	aw	e	cl	1.033	0.685	34
0043-00847	8200	1.94	437309.7	617.90	25-40	aw	e	cl	1.033	0.685	35
0006-00639	4851	5.99	257100.4	613.00	25-40	ow	e	cl	1.033	0.685	36
0041-00761	8023	2.69	427771.7	609.50	25-40	ow	e	cl	1.033	0.685	37
0009-00741	5173	0.58	274610.3	606.70	25-40	ow	e	cl	1.033	0.685	38
0035-00821	7494	3.49	400837.8	606.70	25-40	aw	e	cl	1.033	0.685	39
0007-00633	4976	4.07	263870.2	594.20	25-40	aw	e	cl	1.033	0.685	40
0019-00561	6060	3.50	322925.5	578.40	25-40	aw	e	cl	1.033	0.685	41
0027-00906	6736	1.59	359936.9	569.20	25-40	aw	e	cl	1.033	0.685	42
0009-01195	774	0.35	40205.3	566.80	25-40	aw	e	cl	1.033	0.685	43
0027-01119	2405	8.15	128524.5	540.30	25-40	aw	e	cl	1.033	0.685	44
0017-00870	1527	4.12	80710.6	536.20	25-40	aw	e	cl	1.033	0.685	45
0035-01023	3198	4.87	170824.1	526.70	25-40	aw	e	cl	1.033	0.685	46
0079-00871	11526	1.06	614806.9	521.70	25-40	aw	e	cl	1.033	0.685	47
0019-00376	6054	7.40	322583.8	509.10	25-40	aw	e	cl	1.033	0.685	48
0041-00764	8036	13.20	428517.9	506.30	25-40	aw	e	cl	1.033	0.685	49
0045-00744	8438	3.74	450523.8	499.10	25-40	aw	e	cl	1.033	0.685	50
0009-01212	779	2.52	40464.2	491.60	25-40	aw	e	cl	1.033	0.685	51
0018-01020	1613	0.77	85410.8	465.30	25-40	aw	e	cl	1.033	0.685	52
0026-01048	6691	12.53	357387.8	463.20	25-40	aw	e	cl	1.033	0.685	53
0043-01142	3905	0.80	206728.1	462.60	25-40	aw	e	cl	1.033	0.685	54
0041-00768	8092	18.30	431547.4	450.70	25-40	aw	e	cl	1.033	0.685	55
0041-00763	8035	3.76	428452.4	439.90	25-40	aw	e	cl	1.033	0.685	56



Area No.	Pipe No.	DuGW [ft]	Distance, [ft]	Length [in]	Est. Depth [%WT]	Rel. Pos.	Rad. Pos.	Type	Lr	Kr	Ranking
0036-00962	3234	1.99	172724.7	437.30	25-40	aw	e	cl	1.033	0.685	57
0007-00964	628	0.31	32311.9	434.00	25-40	aw	e	cl	1.033	0.685	58
0020-01040	1829	12.19	96730.4	419.00	25-40	aw	e	cl	1.033	0.685	59
0008-00589	5079	1.18	269457.1	412.20	25-40	aw	e	cl	1.033	0.685	60
0005-01008	4748	7.11	251772.0	398.90	25-40	aw	e	cl	1.033	0.685	61
0056-00825	9444	25.91	504773.5	374.70	25-40	aw	e	cl	1.033	0.685	62
0031-01196	2774	13.89	147913.0	367.20	25-40	aw	e	cl	1.033	0.685	63
0016-00054	5726	15.05	305160.6	357.70	25-40	aw	e	cl	1.033	0.685	64
0048-00339	8677	23.14	463456.1	350.20	25-40	aw	e	cl	1.033	0.685	65
0016-00739	5740	0.13	305935.3	336.60	25-40	aw	e	cl	1.033	0.685	66
0042-01001	3897	5.90	206369.7	323.40	25-40	aw	e	cl	1.033	0.684	67
0034-00446	3086	5.74	164910.4	321.10	25-40	aw	e	cl	1.033	0.684	68
0045-00108	8381	0.60	447385.7	310.40	25-40	aw	e	cl	1.033	0.684	69
0042-01006	3885	1.67	205715.7	273.00	25-40	aw	e	cl	1.033	0.684	70
0053-00648	9190	19.77	491112.9	260.90	25-40	aw	e	cl	1.033	0.684	71
0041-00766	8072	4.26	430424.1	260.70	25-40	aw	e	cl	1.033	0.684	72
0016-01139	1479	13.85	78183.1	241.10	25-40	aw	e	cl	1.033	0.684	73
0023-00611	2099	9.33	111668.0	232.60	25-40	aw	e	cl	1.033	0.684	74
0024-00833	2146	5.28	114218.1	203.60	25-40	aw	e	cl	1.033	0.684	75
0034-01059	3083	8.84	164736.9	200.30	25-40	aw	e	cl	1.033	0.684	76
0006-01009	567	19.88	28948.8	173.00	25-40	aw	e	cl	1.033	0.684	77
0055-00493	9371	6.88	500710.5	9.20	25-40	iw	e	cl	1.023	0.700	78
0064-00597	10110	8.34	540615.9	141.50	25-40	aw	e	cl	1.033	0.683	79
0004-01006	379	25.40	19075.5	136.10	25-40	aw	e	cl	1.033	0.683	80
0034-00339	3079	48.83	164548.8	116.60	25-40	aw	e	cl	1.033	0.683	81
0004-01281	390	0.66	19669.8	111.40	25-40	aw	e	cl	1.033	0.683	82
0031-00297	2796	24.85	149107.6	107.80	25-40	aw	e	cl	1.033	0.683	83
0020-00623	6139	29.86	327134.9	83.30	25-40	aw	e	cl	1.033	0.682	84
0011-00128	5287	16.91	280875.9	74.40	25-40	aw	e	cl	1.033	0.682	85
0036-00553	7606	51.89	405579.2	70.00	25-40	aw	e	cl	1.033	0.682	86
0004-01265	382	32.29	19243.8	63.30	25-40	aw	e	cl	1.033	0.681	87
0056-00061	9391	28.79	501855.4	62.50	25-40	aw	e	cl	1.033	0.681	88
0046-00713	8491	30.55	453528.5	60.90	25-40	aw	e	nl	1.033	0.681	89
0031-00322	2798	52.04	149244.0	54.10	25-40	aw	e	cl	1.033	0.681	90
0023-00609	2083	25.58	110759.7	50.50	25-40	aw	e	cl	1.033	0.680	91
0004-01350	355	44.24	17798.0	50.30	25-40	aw	e	cl	1.033	0.680	92
0003-01589	278	10.81	13592.0	49.80	25-40	aw	e	cl	1.033	0.680	93
0012-00638	5440	53.51	289408.3	46.90	25-40	aw	e	cl	1.033	0.680	94
0082-00614	11869	47.49	633086.5	42.10	25-40	aw	e	cl	1.034	0.679	95
0031-00312	2797	12.30	149146.4	40.30	25-40	aw	e	cl	1.034	0.679	96
0037-00654	7714	25.26	411550.4	39.30	25-40	aw	e	cl	1.034	0.679	97
0004-01376	379	45.44	19095.5	32.00	25-40	aw	e	cl	1.034	0.677	98
0025-00809	2226	17.77	118586.9	30.70	25-40	aw	e	cl	1.034	0.677	99
0031-00130	2780	55.96	148264.0	30.30	25-40	aw	e	cl	1.034	0.677	100
0012-00612	5440	16.56	289371.4	29.50	25-40	aw	e	cl	1.034	0.677	101
0031-00303	2796	37.77	149120.5	28.20	25-40	aw	e	cl	1.034	0.676	102
0035-00131	3140	15.14	167706.0	26.80	25-40	aw	e	cl	1.034	0.676	103
0038-00900	7823	12.84	417548.4	26.40	25-40	aw	e	cl	1.034	0.675	104
0035-01008	3186	19.77	170179.6	25.20	25-40	aw	e	cl	1.034	0.675	105
0035-00599	3186	22.75	170182.6	24.30	25-40	aw	e	cl	1.034	0.675	106
0031-00096	2777	55.55	148094.5	21.60	25-40	aw	e	cl	1.034	0.673	107
0045-01315	4173	49.41	221277.1	21.20	25-40	aw	e	nl	1.034	0.673	108
0040-00352	3631	7.40	194041.1	20.80	25-40	aw	e	cl	1.034	0.673	109
0033-01048	7287	21.83	389678.5	20.70	25-40	aw	e	cl	1.034	0.673	110
0027-00109	2405	49.24	128565.6	20.60	25-40	aw	e	cl	1.034	0.673	111
0045-01421	4087	42.60	216558.5	20.10	25-40	aw	e	cl	1.034	0.673	112
0044-00572	4035	43.32	214037.3	18.80	25-40	aw	e	cl	1.034	0.672	113
0014-00345	5589	8.08	297509.7	17.00	25-40	aw	e	nl	1.034	0.670	114
0024-00674	2201	29.22	117211.4	16.90	25-40	aw	e	cl	1.034	0.670	115
0012-00684	5384	10.37	286318.9	16.90	25-40	aw	e	cl	1.034	0.670	116



Area No.	Pipe No.	DuGW [ft]	Distance, [ft]	Length [in]	Est. Depth [%WT]	Rel. Pos.	Rad. Pos.	Type	Lr	Kr	Ranking
0034-00974	7423	9.04	396981.6	16.90	25-40	aw	e	cl	1.034	0.670	117
0030-01025	2753	23.17	146769.7	6.00	25-40	ow	nd	cl	1.040	0.661	118
0038-00382	7781	16.70	415299.3	16.20	25-40	ow	e	cl	1.034	0.669	119
0045-00537	4120	43.99	218366.9	16.00	25-40	ow	e	cl	1.034	0.669	120
0031-00944	7096	1.80	379099.8	15.30	25-40	ow	e	cl	1.034	0.668	121
0004-01271	383	32.42	19299.8	15.10	25-40	ow	e	cl	1.034	0.668	122
0071-00693	10824	42.33	577647.3	14.60	25-40	ow	e	cl	1.034	0.668	123
0040-00875	3681	10.13	196677.9	14.40	25-40	ow	e	cl	1.034	0.668	124
0004-01261	381	47.65	19205.4	13.20	25-40	ow	e	nl	1.034	0.666	125
0045-01438	4125	46.28	218658.2	12.50	25-40	ow	e	cl	1.034	0.665	126
0003-00194	4556	8.11	241641.4	12.30	25-40	ow	e	nl	1.034	0.664	127
0016-00731	5764	52.85	306770.0	12.00	25-40	ow	e	cl	1.034	0.664	128
0044-00300	8328	7.37	444401.8	12.00	25-40	ow	e	nl	1.034	0.664	129
0031-00928	2843	8.07	151542.3	11.20	25-40	ow	e	cl	1.034	0.662	130
0045-00798	4137	16.59	219284.1	11.20	25-40	ow	e	cl	1.034	0.662	131
0041-00533	8076	14.37	430652.6	11.20	25-40	ow	e	cl	1.034	0.662	132
0034-01048	7427	20.70	397227.9	11.00	25-40	ow	e	cl	1.034	0.661	133
0065-00286	10270	45.47	547744.8	10.60	25-40	ow	e	cl	1.034	0.661	134
0005-01022	397	42.00	20063.3	10.30	25-40	ow	e	nl	1.032	0.660	135
0031-00959	2843	40.46	151574.7	10.00	25-40	ow	e	cl	1.030	0.660	136
0036-00855	7609	3.34	405704.9	9.90	25-40	ow	e	cl	1.029	0.659	137
0030-00309	2696	57.13	143617.7	5.60	25-40	ow	nd	cl	1.030	0.657	138
0031-00912	7115	29.67	380119.2	9.80	25-40	ow	e	nl	1.028	0.659	139
0059-00059	9654	25.92	516165.9	9.70	25-40	ow	e	nl	1.027	0.659	140
0043-00447	3952	35.11	209419.2	9.50	25-40	ow	e	cl	1.025	0.658	141
0004-00471	4705	18.02	249355.1	8.80	25-40	ow	e	nl	1.019	0.656	142
0024-00510	2193	34.65	116774.4	8.60	25-40	ow	e	cl	1.016	0.656	143
0036-00008	7557	2.88	402825.6	8.50	25-40	ow	e	cl	1.015	0.655	144
0046-00598	4220	21.50	223833.9	8.40	25-40	ow	e	cl	1.014	0.655	145
0045-00197	8398	26.98	448391.9	8.10	25-40	ow	e	cl	1.011	0.654	146
0062-00514	10004	51.80	535057.0	6.50	25-40	iw	e	cl	0.987	0.687	147
0004-01393	382	49.34	19260.9	7.90	25-40	ow	e	cl	1.008	0.653	148
0031-00971	2843	55.33	151589.5	7.90	25-40	ow	e	nl	1.008	0.653	149
0059-00641	9683	38.99	517718.0	4.30	25-40	iw	i	cl	0.992	0.677	150
0030-01034	2753	32.32	146778.9	4.90	25-40	ow	nd	cl	1.011	0.647	151
0010-00021	5180	33.19	275027.0	7.70	25-40	ow	e	cl	1.006	0.652	152
0082-00822	11829	15.76	630916.6	7.70	25-40	ow	e	cl	1.006	0.652	153
0041-00085	8028	6.22	428063.5	7.60	25-40	ow	e	cl	1.004	0.652	154
0028-00645	2555	17.80	136610.8	6.20	25-40	iw	e	cl	0.981	0.685	155
0026-00642	2341	29.64	125019.3	7.50	25-40	ow	e	cl	1.003	0.651	156
0073-00150	10986	46.13	586020.2	7.50	25-40	ow	e	nl	1.003	0.651	157
0051-00578	9006	34.96	481139.4	6.10	25-40	iw	e	cl	0.979	0.685	158
0045-00527	4120	25.51	218348.4	7.30	25-40	ow	e	cl	1.000	0.650	159
0056-01075	9464	48.29	505874.3	7.30	25-40	aw	e	cl	1.000	0.650	160
0024-00657	2201	0.44	117182.6	7.20	25-40	aw	e	cl	0.998	0.650	161
0039-00458	3548	10.11	189549.0	7.20	25-40	aw	e	cl	0.998	0.650	162
0043-00723	3969	34.78	210363.2	7.20	25-40	aw	e	cl	0.998	0.650	163
0081-00258	11748	26.52	626503.5	7.20	25-40	aw	e	cl	0.998	0.650	164
0041-00393	8064	21.90	429994.8	5.90	25-40	iw	e	cl	0.975	0.683	165
0012-00161	5394	17.01	286909.5	7.10	25-40	aw	e	cl	0.997	0.649	166
0056-00944	9451	10.72	505150.2	7.10	25-40	aw	e	cl	0.997	0.649	167
0072-00753	10944	0.83	583911.9	7.10	25-40	aw	e	nl	0.997	0.649	168
0004-00804	357	27.41	17885.6	6.90	25-40	aw	e	cl	0.994	0.648	169
0031-00689	7129	31.14	380929.5	6.90	25-40	aw	e	cl	0.994	0.648	170
0035-00555	7509	25.66	401714.3	6.90	25-40	aw	e	cl	0.994	0.648	171
0040-00955	3645	49.95	194837.5	6.70	25-40	aw	e	cl	0.990	0.647	172
0077-01196	11360	7.63	606475.1	6.60	25-40	aw	e	cl	0.989	0.647	173
0027-00110	2406	5.95	128581.5	5.50	25-40	iw	e	cl	0.966	0.679	174
0005-00699	4781	32.09	253300.0	5.50	25-40	iw	e	cl	0.966	0.679	175
0039-00490	7859	17.63	419301.8	6.50	25-40	aw	e	nl	0.987	0.646	176



Area No.	Pipe No.	DuGW [ft]	Distance, [ft]	Length [in]	Est. Depth [%WT]	Rel. Pos.	Rad. Pos.	Type	Lr	Kr	Ranking
0039-00777	3588	4.83	191748.4	6.40	25-40	aw	e	cl	0.985	0.645	177
0033-00367	3004	52.16	160490.1	6.30	25-40	aw	e	cl	0.983	0.645	178
0044-01047	4046	2.36	214601.8	6.30	25-40	aw	e	cl	0.983	0.645	179
0033-00900	7333	38.78	392261.1	6.30	25-40	aw	e	cl	0.983	0.645	180
0072-00627	10931	6.36	583228.1	6.30	25-40	aw	e	cl	0.983	0.645	181
0016-00359	5767	38.01	306910.4	6.20	25-40	aw	e	cl	0.981	0.644	182
0034-00279	3077	38.93	164424.7	4.10	25-40	aw	i	cl	0.985	0.632	183
0043-00096	3915	37.31	207341.0	4.10	25-40	aw	nd	cl	0.985	0.632	184
0004-01048	381	53.20	19210.9	6.00	25-40	aw	e	cl	0.977	0.643	185
0020-01015	1835	31.55	97089.9	6.00	25-40	aw	e	cl	0.977	0.643	186
0034-00952	3122	24.73	166813.1	6.00	25-40	aw	e	cl	0.977	0.643	187
0008-00463	742	45.59	38667.1	5.90	25-40	aw	e	cl	0.975	0.642	188
0008-00126	5008	21.31	265606.7	5.90	25-40	aw	e	cl	0.975	0.642	189
0034-00995	7423	50.91	397023.5	5.90	25-40	aw	e	cl	0.975	0.642	190
0073-00003	10965	33.42	584890.6	5.90	25-40	aw	e	nl	0.975	0.642	191
0013-00652	5522	15.87	293845.5	4.00	25-40	aw	i	cl	0.981	0.630	192
0016-01090	1487	20.58	78616.0	4.90	25-40	iw	e	cl	0.951	0.672	193
0032-00056	7174	16.41	383438.4	5.70	25-40	aw	e	cl	0.971	0.640	194
0082-00336	11829	27.17	630928.0	5.70	25-40	aw	e	cl	0.971	0.640	195
0016-00607	1433	52.65	75643.0	5.60	25-40	aw	e	cl	0.969	0.639	196
0003-00693	4615	47.68	244487.2	5.50	25-40	aw	e	cl	0.966	0.638	197
0058-00888	9564	8.93	511234.5	5.50	25-40	aw	e	nl	0.966	0.638	198
0075-00124	11180	13.64	596330.5	5.50	25-40	aw	e	cl	0.966	0.638	199
0046-00426	4205	39.65	222977.6	5.40	25-40	aw	e	cl	0.964	0.637	200
0025-00041	6536	32.54	348825.0	3.70	25-40	aw	i	cl	0.973	0.623	201
0066-00221	10345	4.15	551925.2	3.70	25-40	aw	i	cl	0.973	0.623	202
0023-00286	2083	32.64	110766.8	5.30	25-40	aw	e	cl	0.961	0.636	203
0041-00518	3756	8.45	200870.6	5.30	25-40	aw	e	cl	0.961	0.636	204
0012-00675	5441	45.07	289457.3	5.30	25-40	aw	e	cl	0.961	0.636	205
0064-00206	10136	45.69	542077.4	5.30	25-40	aw	e	nl	0.961	0.636	206
0020-00119	6105	13.86	325213.1	3.60	25-40	aw	i	nl	0.970	0.620	207
0024-00821	2216	57.39	118041.2	4.50	25-40	iw	e	cl	0.939	0.666	208
0017-00626	1556	9.95	82274.9	5.20	25-40	aw	e	cl	0.959	0.635	209
0046-00116	4183	25.76	221800.7	4.40	25-40	iw	e	cl	0.935	0.665	210
0019-00752	1757	13.95	93230.1	5.10	25-40	aw	e	cl	0.956	0.634	211
0043-00858	3975	2.30	210619.0	5.10	25-40	aw	e	cl	0.956	0.634	212
0013-00542	5514	48.72	293412.1	5.10	25-40	aw	e	cl	0.956	0.634	213
0014-00419	5599	30.20	298116.0	5.10	25-40	aw	e	cl	0.956	0.634	214
0036-00705	7618	7.84	406213.9	5.10	25-40	aw	e	cl	0.956	0.634	215
0039-00491	7859	22.52	419306.7	5.10	25-40	aw	e	nl	0.956	0.634	216



Table 13: Remaining life of sub-critical USCD crack-like and notch-like features that grow to critical size within 20 year. Abbreviations are detailed in appendix.

No.	Area No.	Pipe No.	DuGW [ft]	Distance [ft]	Length [in]	Est. Depth [%WT]	Rel. Pos.	Rad. Pos.	Type	Final Crack Length (in)	Final Crack Depth (in)	Remaining Life (years)
1	0034-00042	3045	21.81	162695.5	5.00	25-40	aw	e	cl	5.20	0.10	0.6
2	0011-00700	5336	58.14	283671.4	3.50	25-40	aw	nd	cl	3.70	0.10	0.6
3	0031-00865	7158	36.42	382543.1	4.90	25-40	aw	e	cl	5.10	0.10	1.7
4	0072-00534	10920	36.82	582709.7	4.90	25-40	aw	e	cl	5.10	0.10	1.7
5	0038-00909	7772	24.98	414787.8	4.80	25-40	aw	e	cl	5.00	0.10	1.7
6	0033-01064	7287	10.72	389667.4	4.70	25-40	aw	e	cl	4.90	0.10	2.0
7	0027-00916	6744	39.22	360393.1	4.60	25-40	aw	e	cl	4.80	0.10	2.4
8	0035-00605	3186	29.88	170189.7	4.90	25-40	aw	e	cl	5.10	0.10	2.8
9	0017-00027	5814	19.54	309501.7	4.80	25-40	aw	e	nl	5.00	0.10	2.8
10	0022-00776	2028	25.01	107813.8	4.10	25-40	iw	e	cl	4.30	0.10	3.0
11	0031-00372	7102	43.12	379434.4	4.50	25-40	aw	e	cl	4.70	0.10	3.4
12	0017-00768	1569	26.96	82975.1	4.70	25-40	aw	e	cl	4.90	0.10	3.4
13	0026-00643	2341	36.60	125026.2	4.70	25-40	aw	e	cl	4.90	0.10	3.4
14	0003-00195	4556	10.01	241643.3	4.70	25-40	aw	e	cl	4.90	0.10	3.4
15	0026-00680	6678	52.90	356699.7	3.90	25-40	iw	e	cl	4.10	0.10	3.5
16	0034-00985	7423	31.24	397003.8	4.40	25-40	aw	e	cl	4.60	0.10	3.7
17	0004-00961	373	38.38	18794.2	4.60	25-40	aw	e	cl	4.80	0.10	4.0
18	0004-01391	382	44.76	19256.3	4.60	25-40	aw	e	cl	4.80	0.10	4.0
19	0040-00118	7946	41.71	423872.5	4.30	25-40	aw	e	cl	4.50	0.10	4.4
20	0060-00759	9813	57.60	524902.7	4.30	25-40	aw	e	cl	4.50	0.10	4.4
21	0047-00861	4358	10.07	231297.4	39.50	25-40	bm	i	cl	39.70	0.10	5.3
22	0027-00399	6745	35.62	360448.5	4.10	25-40	aw	e	cl	4.30	0.10	5.4
23	0046-00005	8464	43.66	452030.4	4.10	25-40	aw	e	cl	4.30	0.10	5.4
24	0055-00462	9364	47.05	500387.3	4.10	25-40	aw	e	cl	4.30	0.10	5.4
25	0077-00393	11357	18.40	606318.4	4.10	25-40	aw	e	cl	4.30	0.10	5.4
26	0027-00588	6763	41.05	361476.6	3.50	25-40	iw	e	cl	3.70	0.10	5.4
27	0030-01141	2762	3.50	147275.3	4.50	25-40	aw	e	cl	4.70	0.10	5.6
28	0045-01437	4125	45.19	218657.1	4.50	25-40	aw	e	cl	4.70	0.10	5.6
29	0005-00008	4722	0.93	250282.6	4.50	25-40	aw	e	nl	4.70	0.10	5.6
30	0004-01259	381	23.13	19180.9	4.40	25-40	aw	e	nl	4.60	0.10	6.2
31	0007-00439	602	17.32	30883.4	4.40	25-40	aw	e	cl	4.60	0.10	6.2
32	0020-00444	6154	7.55	327888.6	3.20	25-40	aw	i	cl	3.40	0.10	6.2
33	0022-00610	2010	48.68	106813.7	3.70	25-40	iw	e	cl	3.90	0.10	6.6
34	0022-00227	6294	21.65	335583.5	4.00	25-40	aw	e	cl	4.20	0.11	6.6
35	0028-00238	6837	41.09	365413.0	4.00	25-40	aw	e	cl	4.20	0.11	6.6
36	0033-00915	7334	9.78	392290.8	3.90	25-40	aw	e	cl	4.10	0.11	6.7
37	0034-00989	7423	42.59	397015.2	3.90	25-40	aw	e	cl	4.10	0.11	6.7
38	0035-00172	7455	36.76	398780.5	3.90	25-40	aw	e	cl	4.10	0.11	6.7
39	0035-00421	7483	18.63	400242.0	3.90	25-40	aw	e	nl	4.10	0.11	6.7
40	0047-00531	8601	21.33	459656.3	3.90	25-40	aw	e	nl	4.10	0.11	6.7
41	0068-00082	10509	12.03	560725.7	3.90	25-40	aw	e	nl	4.10	0.11	6.7
42	0078-01240	11510	27.19	613949.8	3.90	25-40	aw	e	nl	4.10	0.11	6.7
43	0007-00814	650	20.76	33551.1	4.30	25-40	aw	e	nl	4.50	0.10	7.3
44	0013-00133	5461	19.67	290564.6	4.30	25-40	aw	e	cl	4.50	0.10	7.3
45	0019-00541	6010	32.81	320185.8	4.30	25-40	aw	e	cl	4.50	0.10	7.3
46	0020-00612	6132	12.47	326707.9	4.30	25-40	aw	e	cl	4.50	0.10	7.3
47	0082-00765	11886	33.87	633986.2	3.80	25-40	aw	e	nl	4.00	0.11	7.4
48	0026-00688	6679	25.88	356731.3	3.70	25-40	aw	e	nl	3.90	0.11	8.3
49	0034-00203	7364	8.70	393773.0	3.70	25-40	aw	e	cl	3.90	0.11	8.3
50	0041-00560	8081	49.75	430980.3	3.70	25-40	aw	e	cl	3.90	0.11	8.3
51	0024-00657	6519	39.48	347974.2	3.60	25-40	aw	e	cl	3.80	0.11	8.4
52	0026-00692	6679	33.65	356739.1	3.60	25-40	aw	e	nl	3.80	0.11	8.4
53	0046-00382	8507	12.85	454395.0	3.60	25-40	aw	e	cl	3.80	0.11	8.4
54	0055-00441	9362	49.48	500272.6	3.60	25-40	aw	e	cl	3.80	0.11	8.4



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No.	Area No.	Pipe No.	DuGW [ft]	Distance [ft]	Length [in]	Est. Depth [%WT]	Rel. Pos.	Rad. Pos.	Type	Final Crack Length (in)	Final Crack Depth (in)	Remaining Life (years)
55	0018-00050	1587	13.28	83971.2	4.10	25-40	aw	e	nl	4.30	0.10	8.9
56	0018-00411	1624	27.99	86043.4	4.10	25-40	aw	e	cl	4.30	0.10	8.9
57	0043-00042	3907	52.68	206896.4	4.10	25-40	aw	e	cl	4.30	0.10	8.9
58	0058-00558	9608	52.48	513649.3	3.10	25-40	iw	e	cl	3.30	0.11	9.0
59	0022-00385	6327	25.32	337506.8	3.50	25-40	aw	e	cl	3.70	0.11	10.0
60	0023-00300	6403	13.57	341658.4	3.50	25-40	aw	e	cl	3.70	0.11	10.0
61	0031-00528	7115	23.85	380113.3	3.50	25-40	aw	e	cl	3.70	0.11	10.0
62	0032-00685	7199	3.66	384831.0	3.50	25-40	aw	e	cl	3.70	0.11	10.0
63	0034-00036	7350	7.38	393135.8	3.50	25-40	aw	e	cl	3.70	0.11	10.0
64	0039-00130	7837	4.91	418279.8	3.50	25-40	aw	e	cl	3.70	0.11	10.0
65	0022-00286	6303	26.77	336113.7	3.40	25-40	aw	e	cl	3.60	0.11	10.1
66	0032-00149	7187	56.39	384213.6	3.40	25-40	aw	e	cl	3.60	0.11	10.1
67	0038-00919	7817	55.61	417250.1	3.40	25-40	aw	e	nl	3.60	0.11	10.1
68	0048-00966	8736	21.71	466652.0	3.40	25-40	aw	e	cl	3.60	0.11	10.1
69	0080-00392	11659	5.87	621729.6	3.40	25-40	aw	e	cl	3.10	0.11	10.9
70	0050-00613	8895	52.55	475067.5	2.90	25-40	iw	e	cl	4.20	0.11	11.0
71	0001-00933	96	49.44	4386.3	4.00	25-40	aw	e	nl	4.20	0.11	11.0
72	0004-01396	382	51.35	19262.9	4.00	25-40	aw	e	cl	4.20	0.11	11.0
73	0039-00636	3567	33.35	190658.5	4.00	25-40	aw	e	cl	4.20	0.11	11.0
74	0036-00584	3280	42.96	175201.8	3.90	25-40	aw	e	nl	4.10	0.11	11.1
75	0033-00556	2957	29.38	157802.0	8.80	25-40	bm	i	cl	9.00	0.11	11.5
76	0022-00211	6294	0.53	335562.4	3.30	25-40	aw	e	cl	3.50	0.11	11.7
77	0048-00720	8713	41.42	465409.7	3.30	25-40	aw	e	cl	3.50	0.11	11.7
78	0057-00430	9506	13.43	508071.0	3.30	25-40	aw	e	cl	3.50	0.11	11.7
79	0030-00473	7037	30.32	375861.4	3.20	25-40	aw	e	cl	3.40	0.11	11.9
80	0034-00984	7423	30.44	397003.0	3.20	25-40	aw	e	cl	3.40	0.11	11.9
81	0053-00121	9113	22.88	487089.6	3.20	25-40	aw	e	cl	3.40	0.11	11.9
82	0068-00313	10556	57.56	563237.2	3.20	25-40	aw	e	cl	3.40	0.11	11.9
83	0002-00634	206	46.88	9745.5	3.30	25-40	iw	e	cl	3.50	0.11	11.9
84	0022-00429	1994	51.38	105942.4	3.80	25-40	aw	e	cl	4.00	0.11	12.2
85	0024-00678	2201	33.70	117215.9	3.80	25-40	aw	e	cl	4.00	0.11	12.2
86	0022-00380	6324	8.59	337314.7	3.10	25-40	aw	e	cl	3.30	0.11	13.4
87	0022-00502	6332	26.27	337800.8	3.10	25-40	aw	e	cl	3.30	0.11	13.4
88	0031-00646	7123	37.44	380591.2	3.10	25-40	aw	e	nl	3.30	0.11	13.4
89	0077-00428	11360	0.17	606467.6	3.10	25-40	aw	e	cl	3.30	0.11	13.4
90	0082-00189	11814	24.61	630095.6	3.10	25-40	aw	e	cl	3.30	0.11	13.4
91	0082-00606	11869	24.66	633063.7	3.10	25-40	aw	e	cl	3.30	0.11	13.4
92	0021-00629	6262	39.13	333836.3	3.00	25-40	aw	e	cl	3.20	0.11	13.6
93	0018-00124	1597	22.03	84525.4	3.70	25-40	aw	e	cl	3.90	0.11	13.8
94	0036-00392	3259	16.11	174015.5	3.70	25-40	aw	e	cl	3.90	0.11	13.8
95	0038-00026	3413	23.43	182224.9	3.70	25-40	aw	e	cl	3.90	0.11	13.8
96	0003-00197	4556	11.67	241644.9	3.70	25-40	aw	e	cl	3.90	0.11	13.8
97	0004-00521	4633	1.78	245398.4	3.70	25-40	aw	e	cl	3.90	0.11	13.8
98	0012-00110	5380	32.67	286106.4	3.70	25-40	aw	e	cl	3.90	0.11	13.8
99	0018-00175	5938	4.38	316206.4	3.70	25-40	aw	e	cl	3.90	0.11	13.8
100	0024-00859	2193	33.32	116773.1	3.60	25-40	aw	e	cl	3.80	0.11	14.0
101	0041-00253	3719	24.10	198750.4	3.60	25-40	aw	e	cl	3.80	0.11	14.0
102	0043-00144	3921	5.76	207636.5	3.60	25-40	aw	e	cl	3.80	0.11	14.0
103	0039-00281	7846	13.95	418774.4	2.90	25-40	aw	e	cl	3.10	0.11	15.2
104	0046-00313	8497	24.21	453823.5	2.90	25-40	aw	e	cl	3.10	0.11	15.2
105	0075-00116	11179	36.01	596293.7	2.90	25-40	aw	e	cl	3.10	0.11	15.2
106	0075-00118	11179	42.99	596300.6	2.90	25-40	aw	e	cl	3.10	0.11	15.2
107	0026-00697	6679	37.41	356742.8	2.80	25-40	aw	e	nl	3.00	0.11	15.7
108	0034-00998	7423	52.40	397025.0	2.80	25-40	aw	e	cl	3.00	0.11	15.7
109	0036-00708	7618	12.56	406218.6	2.80	25-40	aw	e	cl	3.00	0.11	15.7
110	0038-00898	7817	57.43	417252.0	2.80	25-40	aw	e	nl	3.00	0.11	15.7
111	0050-00911	8841	10.73	472267.6	2.80	25-40	aw	e	cl	3.00	0.11	15.7
112	0082-00067	11803	53.93	629537.5	2.80	25-40	aw	e	cl	3.00	0.11	15.7



No.	Area No.	Pipe No.	DuGW [ft]	Distance [ft]	Length [in]	Est. Depth [%WT]	Rel. Pos.	Rod. Pos.	Type	Final Crack Length (in)	Final Crack Depth (in)	Remaining Life (years)
113	0036-00389	3258	49.51	173990.7	2.70	25-40	aw	i	cl	2.90	0.11	15.8
114	0005-00103	399	37.89	20166.6	3.50	25-40	aw	e	nl	3.70	0.11	16.6
115	0026-01261	2393	12.39	127858.1	3.50	25-40	aw	e	cl	3.70	0.11	16.6
116	0036-00590	3280	52.27	175211.1	3.50	25-40	aw	e	nl	3.70	0.11	16.6
117	0045-01113	4161	15.55	220562.0	3.50	25-40	aw	e	cl	3.70	0.11	16.6
118	0014-00114	5548	38.28	295250.8	3.50	25-40	aw	e	cl	3.70	0.11	16.6
119	0016-00639	5801	0.29	308753.4	3.50	25-40	aw	e	cl	3.70	0.11	16.6
120	0033-01045	7287	8.43	389665.1	2.70	25-40	aw	e	cl	2.90	0.11	17.1
121	0039-00287	7846	26.07	418786.5	2.70	25-40	aw	e	nl	2.90	0.11	17.1
122	0033-00038	2956	31.46	157745.0	11.70	25-40	bm	e	cl	11.90	0.11	17.6
123	0023-00063	6365	21.45	339584.0	2.60	25-40	aw	e	nl	2.80	0.11	18.7
124	0023-00088	6373	6.40	340038.5	2.60	25-40	aw	e	cl	2.80	0.11	18.7
125	0031-00289	7098	8.20	379189.0	2.60	25-40	aw	e	cl	2.80	0.11	18.7
126	0031-00625	7122	5.03	380501.4	2.60	25-40	aw	e	cl	2.80	0.11	18.7
127	0036-00363	7590	11.40	404661.0	2.60	25-40	aw	e	cl	2.80	0.11	18.7
128	0056-00256	9410	31.73	502859.5	2.60	25-40	aw	e	cl	2.80	0.11	18.7
129	0066-00212	10344	53.36	551915.3	2.60	25-40	aw	e	cl	2.80	0.11	18.7
130	0011-00326	5312	56.24	282297.9	2.60	25-40	aw	i	cl	2.80	0.11	18.8
131	0021-00118	6192	55.07	330039.4	2.20	25-40	aw	i	cl	2.40	0.11	19.2
132	0006-00395	4866	19.66	257918.6	2.80	25-40	iw	e	cl	3.00	0.11	19.3
133	0003-01619	288	6.74	14147.6	3.30	25-40	aw	e	nl	3.50	0.11	19.4
134	0004-00854	363	57.26	18242.4	3.30	25-40	aw	e	cl	3.50	0.11	19.4
135	0004-00964	373	50.21	18806.1	3.30	25-40	aw	e	cl	3.50	0.11	19.4
136	0024-00512	2193	49.64	116789.4	3.30	25-40	aw	e	cl	3.50	0.11	19.4
137	0014-00283	5576	58.27	296814.2	3.30	25-40	aw	e	cl	3.50	0.11	19.4
138	0014-00503	5613	41.27	298910.0	3.30	25-40	aw	e	cl	3.50	0.11	19.4
139	0005-00440	428	57.94	21715.7	3.20	25-40	aw	e	nl	3.40	0.11	19.7
140	0044-00980	4084	56.28	216428.0	3.20	25-40	aw	e	cl	3.40	0.11	19.7
141	0014-00538	5582	24.23	297125.7	3.20	25-40	aw	e	cl	3.40	0.11	19.7



Table 14: Remaining life of field indications that become critical within 20 years. Only cracks and lack of fusion defects have been assessed in relation to fatigue.

Joint #	Inspection type	Type	Feature ID	Absolute Distance	Relative Dist. USGW (ft)	Rel. Pos.	Rad. Pos.	Final Length (in)	Final Depth (in)	Remaining life (year)
6418	PAUT	Crack	2	342403.74	41.44	AW	Ext	6.45	0.099	15.7
6418	PAUT	Crack	7	342406.28	43.98	AW	Ext	18.90	0.093	4.7
6511	Manual	Lack of fusion int	LIN-03	347561.72	29.98	AW	Mw	4.00	0.104	12.1
6903	PAUT	Crack	42	369002.72	15.98	AW	Ext	23.98	0.093	4.6
6903	PAUT	Crack	45	369008.54	21.80	AW	Ext	3.48	0.111	15.7
10737	PAUT	Lack of Fusion	3	572836.42	5.00	IW	Ext	10.93	0.094	7.6

Table 15: Numbers of cumulative excavation vs excavation year. These joint numbers are based on level II FAD assessment at MOP 1440 psi for USCD crack-like and notch-like features. The numbers are also based on fatigue assessment.

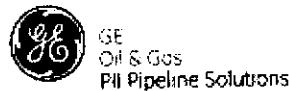
Excavation year	Cumulative critical features	Cumulative digs	Number of digs each year
0	227	195	195
1	229	197	2
2	232	200	3
3	237	202	2
4	245	206	4
5	249	209	3
6	258	217	8
7	271	227	10
8	277	232	5
9	287	240	8
10	294	246	6
11	300	252	6
12	313	261	9
13	316	262	1
14	333	275	13
15	333	275	0
16	346	279	4
17	352	284	5
18	355	285	1
19	363	292	7
20	374	301	9



Table 16: List of all critical features and sub critical features with remaining life less than 20 years in distance order. Features in the same pipe joint or closer than 40 feet in adjoining joints are boxed, and are considered as one dig. Crack assessment is based on level II FAD at MOP 1440 psi.

Red: top 10; Pink: top 20; Blue: top 30; Green: top 40; Brown: field indications. Notch-like features can be considered in lower priority to the equivalent crack-like features, or be considered based on the rankings. Field indications are ranked separately.

No.	Area No.	Pipe No.	DuGW [ft]	Distance [ft]	Rel. Pos.	Type	Pass / Fail	Crack Ranking	Remaining Life (years)	Dig Ranking
1	0001-00933	96	49.44	4386.3	aw	nl	Pass		11.0	249
2	0002-00634	206	46.88	9745.5	iw	cl	Pass		11.9	257
3	0003-01589	278	10.81	13592.0	aw	cl	Fail	93	0	91
4	0003-01619	288	6.74	14147.6	aw	nl	Pass		19.4	291
5	0004-01350	355	44.24	17798.0	ow	cl	Fail	92	0	90
6	0004-00804	357	27.41	17885.6	ow	cl	Fail	169	0	152
7	0004-00854	363	57.26	18242.4	ow	cl	Pass		19.4	292
8	0004-00961	373	38.38	18794.2	ow	cl	Pass		4.0	203
9	0004-00964	373	50.21	18806.1	ow	cl	Pass		19.4	
10	0004-01006	379	25.40	19075.5	aw	cl	Fail	80	0	78
11	0004-01376	379	45.44	19095.5	aw	cl	Fail	98	0	
12	0004-01259	381	23.13	19180.9	aw	nl	Pass		6.2	
13	0004-01261	381	47.65	19205.4	aw	nl	Fail	125	0	
14	0004-01048	381	53.20	19210.9	aw	cl	Fail	185	0	
15	0004-01265	382	32.29	19243.8	aw	cl	Fail	87	0	85
16	0004-01391	382	44.76	19256.3	aw	cl	Pass		4.0	
17	0004-01393	382	49.34	19260.9	aw	cl	Fail	148	0	
18	0004-01396	382	51.35	19262.9	aw	cl	Pass		11.0	
19	0004-01271	383	32.42	19299.8	aw	cl	Fail	122	0	
20	0004-01274	386	37.55	19478.3	aw	nl	Fail	7	0	7
21	0004-01281	390	0.66	19669.8	aw	cl	Fail	82	0	80
22	0005-01022	397	42.00	20063.3	aw	nl	Fail	135	0	124
23	0005-00103	399	37.89	20166.6	aw	nl	Pass		16.6	276
24	0005-00440	428	57.94	21715.7	aw	nl	Pass		19.7	295
25	0006-01009	567	19.88	28948.8	aw	cl	Fail	77	0	75
26	0007-00439	602	17.32	30883.4	aw	cl	Pass		6.2	214
27	0007-00964	628	0.31	32311.9	aw	cl	Fail	58	0	56
28	0007-00814	650	20.76	33551.1	aw	nl	Pass		7.3	224
29	0008-00463	742	45.59	38667.1	aw	cl	Fail	188	0	168
30	0009-01195	774	0.35	40205.3	aw	cl	Fail	43	0	41
31	0009-01212	779	2.52	40464.2	aw	cl	Fail	51	0	49
32	0016-00607	1433	52.65	75643.0	aw	cl	Fail	196	0	174
33	0016-01139	1479	13.85	78183.1	aw	cl	Fail	73	0	71
34	0016-01090	1487	20.58	78616.0	iw	cl	Fail	193	0	172
35	0017-00870	1527	4.12	80710.6	aw	cl	Fail	45	0	43
36	0017-00626	1556	9.95	82274.9	aw	cl	Fail	209	0	186
37	0017-00768	1569	26.96	82975.1	aw	cl	Pass		3.4	201
38	0018-00050	1587	13.28	83971.2	aw	nl	Pass		8.9	234
39	0018-00124	1597	22.03	84525.4	aw	cl	Pass		13.8	264
40	0018-01020	1613	0.77	85410.8	aw	cl	Fail	52	0	50
41	0018-00411	1624	27.99	86043.4	aw	cl	Pass		8.9	235
42	0018-00619	1639	9.06	86845.3	aw	cl	Fail	13	0	12
43	0019-00752	1757	13.95	93230.1	aw	cl	Fail	211	0	188
44	0020-01039	1826	0.28	96559.8	aw	cl	Fail	34	0	32
45	0020-01040	1829	12.19	96730.4	aw	cl	Fail	59	0	57
46	0020-01015	1835	31.55	97089.9	aw	cl	Fail	186	0	166
47	0022-00429	1994	51.38	105942.4	aw	cl	Pass		12.2	258



No.	Area No.	Pipe No.	DuGW [ft]	Distance [ft]	Rel. Pos.	Type	Pass / Fail	Crack Ranking	Remaining Life (years)	Dig Ranking
48	0022-00610	2010	48.68	106813.7	iw	cl	Pass		6.6	216
49	0022-00776	2028	25.01	107813.8	iw	cl	Pass		3.0	
50	0022-00839	2028	34.35	107823.2	iw	cl	Fail	18	0	17
51	0023-00609	2083	25.58	110759.7	aw	cl	Fail	91	0	89
52	0023-00286	2083	32.64	110766.8	aw	cl	Fail	203	0	
53	0023-00611	2099	9.33	111668.0	aw	cl	Fail	74	0	72
54	0024-00833	2146	5.28	114218.1	aw	cl	Fail	75	0	73
55	0024-00859	2193	33.32	116773.1	aw	cl	Pass		14.0	
56	0024-00510	2193	34.65	116774.4	aw	cl	Fail	143	0	131
57	0024-00512	2193	49.64	116789.4	aw	cl	Pass		19.4	
58	0024-00657	2201	0.44	117182.6	aw	cl	Fail	161	0	
59	0024-00674	2201	29.22	117211.4	aw	cl	Fail	115	0	107
60	0024-00678	2201	33.70	117215.9	aw	cl	Pass		12.2	
61	0024-00821	2216	57.39	118041.2	iw	cl	Fail	208	0	185
62	0025-00809	2226	17.77	118586.9	aw	cl	Fail	99	0	95
63	0026-00642	2341	29.64	125019.3	aw	cl	Fail	156	0	141
64	0026-00643	2341	36.60	125026.2	aw	cl	Pass		3.4	
65	0026-01261	2393	12.39	127858.1	aw	cl	Pass		16.6	277
66	0027-01119	2405	8.15	128524.5	aw	cl	Fail	44	0	42
67	0027-00109	2405	49.24	128565.6	aw	cl	Fail	111	0	
68	0027-00110	2406	5.95	128581.5	iw	cl	Fail	174	0	
69	0028-00828	2508	0.95	133980.7	aw	cl	Fail	29	0	27
70	0028-00645	2555	17.80	136610.8	iw	cl	Fail	155	0	140
71	0030-01297	2681	0.38	142720.4	aw	cl	Fail	24	0	22
72	0030-00152	2686	52.06	143050.0	aw	cl	Fail	23	0	21
73	0030-00309	2696	57.13	143617.7	aw	cl	Fail	138	0	126
74	0030-01025	2753	23.17	146769.7	aw	cl	Fail	118	0	
75	0030-01034	2753	32.32	146778.9	aw	cl	Fail	151	0	
76	0030-01041	2753	39.30	146785.9	aw	cl	Fail	10	0	
77	0030-01046	2753	42.32	146788.9	aw	cl	Fail	4	0	4
78	0030-01141	2762	3.50	147275.3	aw	cl	Pass		5.6	212
79	0031-01196	2774	13.89	147913.0	aw	cl	Fail	63	0	61
80	0031-00096	2777	55.55	148094.5	aw	cl	Fail	107	0	100
81	0031-00130	2780	55.96	148264.0	aw	cl	Fail	100	0	96
82	0031-00297	2796	24.85	149107.6	aw	cl	Fail	83	0	81
83	0031-00303	2796	37.77	149120.5	aw	cl	Fail	102	0	
84	0031-00312	2797	12.30	149146.4	aw	cl	Fail	96	0	
85	0031-00322	2798	52.04	149244.0	aw	cl	Fail	90	0	88
86	0031-00928	2843	8.07	151542.3	aw	cl	Fail	130	0	119
87	0031-00959	2843	40.46	151574.7	aw	cl	Fail	136	0	
88	0031-00971	2843	55.33	151589.5	aw	nl	Fail	149	0	
89	0033-00038	2956	31.46	157745.0	bm	cl	Pass		17.6	281
90	0033-00556	2957	29.38	157802.0	bm	cl	Pass		11.5	252
91	0033-00120	2968	7.54	158409.5	aw	nl	Fail	14	0	13
92	0033-00127	2968	31.55	158433.5	aw	nl	Fail	20	0	
93	0033-00367	3004	52.16	160490.1	aw	cl	Fail	178	0	159
94	0034-00042	3045	21.81	162695.5	aw	cl	Pass		0.6	193
95	0034-00279	3077	38.93	164424.7	aw	cl	Fail	183	0	164
96	0034-00339	3079	48.83	164548.8	aw	cl	Fail	81	0	79
97	0034-01059	3083	8.84	164736.9	aw	cl	Fail	76	0	74
98	0034-00446	3086	5.74	164910.4	aw	cl	Fail	68	0	66
99	0034-00952	3122	24.73	166813.1	aw	cl	Fail	187	0	167
100	0035-00131	3140	15.14	167706.0	aw	cl	Fail	103	0	97
101	0035-01008	3186	19.77	170179.6	aw	cl	Fail	105	0	99
102	0035-00599	3186	22.75	170182.6	aw	cl	Fail	106	0	
103	0035-00605	3186	29.88	170189.7	aw	cl	Pass		2.8	
104	0035-01023	3198	4.87	170824.1	aw	cl	Fail	46	0	44



No.	Area No.	Pipe No.	DuGW [ft]	Distance [ft]	Rel. Pos.	Type	Pass / Fail	Crack Ranking	Remaining Life (years)	Dig Ranking
105	0036-00962	3234	1.99	172724.7	aw	cl	Fail	57	0	55
106	0036-00389	3258	49.51	173990.7	aw	cl	Pass		15.8	
107	0036-00392	3259	16.11	174015.5	aw	cl	Pass		13.8	265
108	0036-00584	3280	42.96	175201.8	aw	nl	Pass		11.1	251
109	0036-00590	3280	52.27	175211.1	aw	nl	Pass		16.6	
110	0038-00026	3413	23.43	182224.9	aw	cl	Pass		13.8	266
111	0038-00405	3464	7.76	185031.1	aw	nl	Fail	9	0	9
112	0039-00458	3548	10.11	189549.0	aw	cl	Fail	162	0	145
113	0039-00636	3567	33.35	190658.5	aw	cl	Pass		11.0	250
114	0039-00777	3588	4.83	191748.4	aw	cl	Fail	177	0	158
115	0040-00352	3631	7.40	194041.1	aw	cl	Fail	109	0	102
116	0040-00553	3645	31.53	194819.1	aw	cl	Fail	1	0	1
117	0040-00955	3645	49.95	194837.5	aw	cl	Fail	172	0	
118	0040-00875	3681	10.13	196677.9	aw	cl	Fail	124	0	114
119	0041-00253	3719	24.10	198750.4	aw	cl	Pass		14.0	270
120	0041-00518	3756	8.45	200870.6	aw	cl	Fail	204	0	181
121	0042-01006	3885	1.67	205715.7	aw	cl	Fail	70	0	68
122	0042-01001	3897	5.90	206369.7	aw	cl	Fail	67	0	65
123	0043-01142	3905	0.80	206728.1	aw	cl	Fail	54	0	52
124	0043-00042	3907	52.68	206896.4	aw	cl	Pass		8.9	236
125	0043-00096	3915	37.31	207341.0	aw	cl	Fail	184	0	165
126	0043-00144	3921	5.76	207636.5	aw	cl	Pass		14.0	271
127	0043-00447	3952	35.11	209419.2	aw	cl	Fail	141	0	129
128	0043-00723	3969	34.78	210363.2	aw	cl	Fail	163	0	146
129	0043-00858	3975	2.30	210619.0	aw	cl	Fail	212	0	189
130	0044-00278	4013	45.60	212784.3	aw	cl	Fail	15	0	14
131	0044-00572	4035	43.32	214037.3	aw	cl	Fail	113	0	105
132	0044-01047	4046	2.36	214601.8	aw	cl	Fail	179	0	160
133	0044-00980	4084	56.28	216428.0	aw	cl	Pass		19.7	296
134	0045-01421	4087	42.60	216558.5	aw	cl	Fail	112	0	104
135	0045-00527	4120	25.51	218348.4	aw	cl	Fail	159	0	
136	0045-00537	4120	43.99	218366.9	aw	cl	Fail	120	0	111
137	0045-01437	4125	45.19	218657.1	aw	cl	Pass		5.6	
138	0045-01438	4125	46.28	218658.2	aw	cl	Fail	126	0	115
139	0045-00798	4137	16.59	219284.1	aw	cl	Fail	131	0	120
140	0045-01113	4161	15.55	220562.0	aw	cl	Pass		16.6	278
141	0045-01315	4173	49.41	221277.1	aw	nl	Fail	108	0	101
142	0046-00116	4183	25.76	221800.7	iw	cl	Fail	210	0	187
143	0046-00426	4205	39.65	222977.6	aw	cl	Fail	200	0	178
144	0046-00598	4220	21.50	223833.9	aw	cl	Fail	145	0	133
145	0047-00861	4358	10.07	231297.4	bm	cl	Pass		5.3	206
146	0003-00194	4556	8.11	241641.4	aw	nl	Fail	127	0	116
147	0003-00195	4556	10.01	241643.3	aw	cl	Pass		3.4	
148	0003-00197	4556	11.67	241644.9	aw	cl	Pass		13.8	
149	0003-00693	4615	47.68	244487.2	aw	cl	Fail	197	0	175
150	0004-00521	4633	1.78	245398.4	aw	cl	Pass		13.8	267
151	0004-00471	4705	18.02	249355.1	aw	nl	Fail	142	0	130
152	0005-00008	4722	0.93	250282.6	aw	nl	Pass		5.6	213
153	0005-01008	4748	7.11	251772.0	aw	cl	Fail	61	0	59
154	0005-01011	4755	1.91	252154.9	aw	cl	Fail	31	0	29
155	0005-00699	4781	32.09	253300.0	iw	cl	Fail	175	0	156
156	0006-00639	4851	5.99	257100.4	aw	cl	Fail	36	0	34
157	0006-00395	4866	19.66	257918.6	iw	cl	Pass		19.3	290
158	0007-00633	4976	4.07	263870.2	aw	cl	Fail	40	0	38
159	0008-00126	5008	21.31	265606.7	aw	cl	Fail	189	0	169
160	0008-00530	5076	20.18	269308.8	iw	cl	Fail	22	0	20
161	0008-00589	5079	1.18	269457.1	aw	cl	Fail	60	0	58
162	0009-00741	5173	0.58	274610.3	aw	cl	Fail	38	0	36



No.	Area No.	Pipe No.	DuGW [ft]	Distance [ft]	Rel. Pos.	Type	Pass / Fail	Crack Ranking	Remaining Life (years)	Dig Ranking
163	0010-00021	5180	33.19	275027.0	aw	cl	Fail	152	0	137
164	5	5204	8.89	276313.33	AW	Crack	Fail	A4	0.0	A
165	52	5204	45.85	276350.14	IW/AW	LOF & crack	Fail	A7	0.0	
166	0011-00128	5287	16.91	280875.9	aw	cl	Fail	85	0	83
167	0011-00326	5312	56.24	282297.9	aw	cl	Pass		18.8	288
168	0011-00700	5336	58.14	283671.4	aw	cl	Pass		0.6	194
169	0012-00110	5380	32.67	286106.4	aw	cl	Pass		13.8	268
170	0012-00684	5384	10.37	286318.9	aw	cl	Fail	116	0	108
171	0012-00161	5394	17.01	286909.5	aw	cl	Fail	166	0	149
172	0012-00612	5440	16.56	289371.4	aw	cl	Fail	101	0	
173	0012-00638	5440	53.51	289408.3	aw	cl	Fail	94	0	92
174	0012-00675	5441	45.07	289457.3	aw	cl	Fail	205	0	182
175	0013-00133	5461	19.67	290564.6	aw	cl	Pass		7.3	225
176	0013-00542	5514	48.72	293412.1	aw	cl	Fail	213	0	190
177	0013-00652	5522	15.87	293845.5	aw	cl	Fail	192	0	171
178	0014-00114	5548	38.28	295250.8	aw	cl	Pass		16.6	279
179	0014-00283	5576	58.27	296814.2	aw	cl	Pass		19.4	293
180	0014-00538	5582	24.23	297125.7	aw	cl	Pass		19.7	297
181	0014-00345	5589	8.08	297509.7	aw	nl	Fail	114	0	106
182	0014-00419	5599	30.20	298116.0	aw	cl	Fail	214	0	191
183	0014-00503	5613	41.27	298910.0	aw	cl	Pass		19.4	294
184	0016-00054	5726	15.05	305160.6	aw	cl	Fail	64	0	62
185	0016-00739	5740	0.13	305935.3	aw	cl	Fail	66	0	64
186	0016-00731	5764	52.85	306770.0	aw	cl	Fail	128	0	117
187	0016-00359	5767	38.01	306910.4	aw	cl	Fail	182	0	163
188	0016-00735	5770	0.18	307043.5	aw	cl	Fail	25	0	23
189	0016-00639	5801	0.29	308753.4	aw	cl	Pass		16.6	280
190	0017-00027	5814	19.54	309501.7	aw	nl	Pass		2.8	199
191	0018-00175	5938	4.38	316206.4	aw	cl	Pass		13.8	269
192	0019-00536	6005	50.87	319920.2	iw	cl	Fail	17	0	16
193	0019-00541	6010	32.81	320185.8	aw	cl	Pass		7.3	226
194	0019-00376	6054	7.40	322583.8	aw	cl	Fail	48	0	46
195	0019-00561	6060	3.50	322925.5	aw	cl	Fail	41	0	39
196	0020-00609	6102	39.10	325078.6	aw	cl	Fail	6	0	6
197	0020-00119	6105	13.86	325213.1	aw	nl	Fail	207	0	184
198	0020-00169	6106	16.50	325271.9	aw	nl	Fail	8	0	8
199	0020-00612	6132	12.47	326707.9	aw	cl	Pass		7.3	227
200	0020-00623	6139	29.86	327134.9	aw	cl	Fail	84	0	82
201	0020-00444	6154	7.55	327888.6	aw	cl	Pass		6.2	215
202	0021-00118	6192	55.07	330039.4	aw	cl	Pass		19.2	289
203	0021-00629	6262	39.13	333836.3	aw	cl	Pass		13.6	263
204	0022-00211	6294	0.53	335562.4	aw	cl	Pass		11.7	
205	0022-00227	6294	21.65	335583.5	aw	cl	Pass		6.6	217
206	0022-00286	6303	26.77	336113.7	aw	cl	Pass		10.1	243
207	0022-00380	6324	8.59	337314.7	aw	cl	Pass		13.4	259
208	0022-00385	6327	25.32	337506.8	aw	cl	Pass		10.0	238
209	0022-00502	6332	26.27	337800.8	aw	cl	Pass		13.4	260
210	0023-00063	6365	21.45	339584.0	aw	nl	Pass		18.7	282
211	0023-00088	6373	6.40	340038.5	aw	cl	Pass		18.7	283
212	0023-00300	6403	13.57	341658.4	aw	cl	Pass		10.0	239
213	2	6418	41.44	342403.74	AW	Crack	Pass		15.7	
214	7	6418	43.98	342406.28	AW	Crack	Pass		4.7	4.7
215	LIN-03	6511	29.98	347561.72	AW	LOF Int	Pass		12.1	
216	0024-00657	6519	39.48	347974.2	aw	cl	Pass		8.4	231
217	0025-00041	6536	32.54	348825.0	aw	cl	Fail	201	0	179
218	0025-00754	6585	0.70	351547.2	aw	cl	Fail	26	0	24
219	0026-00680	6678	52.90	356699.7	iw	cl	Pass		3.5	202



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No.	Area No.	Pipe No.	DuGW [ft]	Distance [ft]	Rel. Pos.	Type	Pass / Fail	Crack Ranking	Remaining Life (years)	Dig Ranking
220	0026-00688	6679	25.88	356731.3	aw	nl	Pass		8.3	
221	0026-00692	6679	33.65	356739.1	aw	nl	Pass		8.4	
222	0026-00697	6679	37.41	356742.8	aw	nl	Pass		15.7	
223	0026-01048	6691	12.53	357387.8	aw	cl	Fail	53	0	51
224	0027-00906	6736	1.59	359936.9	aw	cl	Fail	42	0	40
225	0027-00916	6744	39.22	360393.1	aw	cl	Pass		2.4	198
226	0027-00399	6745	35.62	360448.5	aw	cl	Pass		5.4	207
227	0027-00588	6763	41.05	361476.6	iw	cl	Pass		5.4	211
228	0028-00238	6837	41.09	365413.0	aw	cl	Pass		6.6	218
229	47	6903	0.79	368987.52	AW	Crack	Fail	A5	0.0	
230	16	6903	7.97	368994.70	AW	Crack	Fail	A1	0.0	A
231	21	6903	9.98	368996.71	AW	Crack	Fail	A10	0.0	
232	22	6903	10.36	368997.09	AW	Crack	Fail	A8	0.0	
233	27	6903	12.49	368999.23	IW	Crack	Fail	A2	0.0	
234	42	6903	15.98	369002.72	AW	Crack	Pass		4.6	
235	43	6903	17.96	369004.70	AW	Crack	Fail	A9	0.0	
236	45	6903	21.80	369008.54	AW	Crack	Pass		15.7	
237	0030-00473	7037	30.32	375861.4	aw	cl	Pass		11.9	255
238	0031-00944	7096	1.80	379099.8	aw	cl	Fail	121	0	112
239	0031-00289	7098	8.20	379189.0	aw	cl	Pass		18.7	284
240	0031-00372	7102	43.12	379434.4	aw	cl	Pass		3.4	200
241	0031-00528	7115	23.85	380113.3	aw	cl	Pass		10.0	
242	0031-00912	7115	29.67	380119.2	aw	nl	Fail	139	0	127
243	0031-00625	7122	5.03	380501.4	aw	cl	Pass		18.7	285
244	0031-00646	7123	37.44	380591.2	aw	nl	Pass		13.4	261
245	0031-00689	7129	31.14	380929.5	aw	cl	Fail	170	0	153
246	0031-00865	7158	36.42	382543.1	aw	cl	Pass		1.7	195
247	0032-00056	7174	16.41	383438.4	aw	cl	Fail	194	0	173
248	0032-00149	7187	56.39	384213.6	aw	cl	Pass		10.1	244
249	0032-00685	7199	3.66	384831.0	aw	cl	Pass		10.0	240
250	0033-01045	7287	8.43	389665.1	aw	cl	Pass		17.1	
251	0033-01064	7287	10.72	389667.4	aw	cl	Pass		2.0	
252	0033-01048	7287	21.83	389678.5	aw	cl	Fail	110	0	103
253	0033-01077	7301	23.12	390453.4	aw	cl	Fail	3	0	3
254	0033-00900	7333	38.78	392261.1	aw	cl	Fail	180	0	161
255	0033-00915	7334	9.78	392290.8	aw	cl	Pass		6.7	
256	0034-00036	7350	7.38	393135.8	aw	cl	Pass		10.0	241
257	0034-00203	7364	8.70	393773.0	aw	cl	Pass		8.3	229
258	0034-00974	7423	9.04	396981.6	aw	cl	Fail	117	0	109
259	0034-00984	7423	30.44	397003.0	aw	cl	Pass		11.9	
260	0034-00985	7423	31.24	397003.8	aw	cl	Pass		3.7	
261	0034-00989	7423	42.59	397015.2	aw	cl	Pass		6.7	
262	0034-00995	7423	50.91	397023.5	aw	cl	Fail	190	0	
263	0034-00998	7423	52.40	397025.0	aw	cl	Pass		15.7	
264	0034-01048	7427	20.70	397227.9	aw	cl	Fail	133	0	122
265	0035-00172	7455	36.76	398780.5	aw	cl	Pass		6.7	219
266	0035-00798	7467	34.89	399384.6	aw	cl	Fail	12	0	11
267	0035-00421	7483	18.63	400242.0	aw	nl	Pass		6.7	220
268	0035-00821	7494	3.49	400837.8	aw	cl	Fail	39	0	37
269	0035-00555	7509	25.66	401714.3	aw	cl	Fail	171	0	154
270	0036-00008	7557	2.88	402825.6	aw	cl	Fail	144	0	132
271	0036-00363	7590	11.40	404661.0	aw	cl	Pass		18.7	286
272	0036-00553	7606	51.89	405579.2	aw	cl	Fail	86	0	84
273	0036-00855	7609	3.34	405704.9	aw	cl	Fail	137	0	125
274	0036-00705	7618	7.84	406213.9	aw	cl	Fail	215	0	192
275	0036-00708	7618	12.56	406218.6	aw	cl	Pass		15.7	
276	0036-00804	7634	8.85	407088.5	aw	cl	Fail	2	0	2
277	0037-00654	7714	25.26	411550.4	aw	cl	Fail	97	0	94



No.	Area No.	Pipe No.	DuGW [ft]	Distance [ft]	Rel. Pos.	Type	Pass / Fail	Crack Ranking	Remaining Life (years)	Dig Ranking
278	0038-00190	7757	20.40	413933.4	aw	cl	Fail	16	0	15
279	0038-00909	7772	24.98	414787.8	aw	cl	Pass		1.7	197
280	0038-00382	7781	16.70	415299.3	aw	cl	Fail	119	0	110
281	0038-00919	7817	55.61	417250.1	aw	nl	Pass		10.1	245
282	0038-00898	7817	57.43	417252.0	aw	nl	Pass		15.7	
283	0038-00900	7823	12.84	417548.4	aw	cl	Fail	104	0	98
284	0039-00130	7837	4.91	418279.8	aw	cl	Pass		10.0	242
285	0039-00281	7846	13.95	418774.4	aw	cl	Pass		15.2	272
286	0039-00287	7846	26.07	418786.5	aw	nl	Pass		17.1	
287	0039-00490	7859	17.63	419301.8	aw	nl	Fail	176	0	157
288	0039-00491	7859	22.52	419306.7	aw	nl	Fail	216	0	
289	0040-00118	7946	41.71	423872.5	aw	cl	Pass		4.4	204
290	0041-00761	8023	2.69	427771.7	aw	cl	Fail	37	0	35
291	0041-00085	8028	6.22	428063.5	aw	cl	Fail	154	0	139
292	0041-00763	8035	3.76	428452.4	aw	cl	Fail	56	0	54
293	0041-00764	8036	13.20	428517.9	aw	cl	Fail	49	0	47
294	0041-00393	8064	21.90	429994.8	iw	cl	Fail	165	0	148
295	0041-00766	8072	4.26	430424.1	aw	cl	Fail	72	0	70
296	0041-00533	8076	14.37	430652.6	aw	cl	Fail	132	0	121
297	0041-00560	8081	49.75	430980.3	aw	cl	Pass		8.3	230
298	0041-00767	8084	2.32	431099.2	aw	cl	Fail	28	0	26
299	0041-00768	8092	18.30	431547.4	aw	cl	Fail	55	0	53
300	0043-00847	8200	1.94	437309.7	aw	cl	Fail	35	0	33
301	0044-00300	8328	7.37	444401.8	aw	nl	Fail	129	0	118
302	0045-00108	8381	0.60	447385.7	aw	cl	Fail	69	0	67
303	0045-00197	8398	26.98	448391.9	aw	cl	Fail	146	0	134
304	0045-00745	8405	0.51	448776.6	aw	cl	Fail	32	0	30
305	0045-00744	8438	3.74	450523.8	aw	cl	Fail	50	0	48
306	0046-00005	8464	43.66	452030.4	aw	cl	Pass		5.4	208
307	0046-00713	8491	30.55	453528.5	aw	nl	Fail	89	0	87
308	0046-00313	8497	24.21	453823.5	aw	cl	Pass		15.2	273
309	0046-00382	8507	12.85	454395.0	aw	cl	Pass		8.4	232
310	0047-00531	8601	21.33	459656.3	aw	nl	Pass		6.7	221
311	0048-00339	8677	23.14	463456.1	aw	cl	Fail	65	0	63
312	0048-00720	8713	41.42	465409.7	aw	cl	Pass		11.7	253
313	0048-00966	8736	21.71	466652.0	aw	cl	Pass		10.1	246
314	0049-00207	8769	27.53	468346.4	aw	nl	Fail	5	0	5
315	0050-00911	8841	10.73	472267.6	aw	cl	Pass		15.7	274
316	0050-00613	8895	52.55	475067.5	iw	cl	Pass		10.9	248
317	0051-00578	9006	34.96	481139.4	iw	cl	Fail	158	0	143
318	0052-00521	9091	5.45	485884.4	iw	cl	Fail	21	0	19
319	0053-00121	9113	22.88	487089.6	aw	cl	Pass		11.9	256
320	0053-00648	9190	19.77	491112.9	aw	cl	Fail	71	0	69
321	0055-00441	9362	49.48	500272.6	aw	cl	Pass		8.4	233
322	0055-00462	9364	47.05	500387.3	aw	cl	Pass		5.4	209
323	0055-00493	9371	6.88	500710.5	iw	cl	Fail	78	0	76
324	0056-00061	9391	28.79	501855.4	aw	cl	Fail	88	0	86
325	0056-00256	9410	31.73	502859.5	aw	cl	Pass		18.7	287
326	0056-00825	9444	25.91	504773.5	aw	cl	Fail	62	0	60
327	0056-00944	9451	10.72	505150.2	aw	cl	Fail	167	0	150
328	0056-01075	9464	48.29	505874.3	aw	cl	Fail	160	0	144
329	0057-00430	9506	13.43	508071.0	aw	cl	Pass		11.7	254
330	0058-00888	9564	8.93	511234.5	aw	nl	Fail	198	0	176
331	0058-00558	9608	52.48	513649.3	iw	cl	Pass		9.0	237
332	0059-00059	9654	25.92	516165.9	aw	nl	Fail	140	0	128
333	0059-00641	9683	38.99	517718.0	iw	cl	Fail	150	0	136
334	0060-00371	9775	45.75	522736.0	aw	nl	Fail	11	0	10
335	0060-00759	9813	57.60	524902.7	aw	cl	Pass		4.4	205



No.	Area No.	Pipe No.	DuGW [ft]	Distance [ft]	Rel. Pos.	Type	Pass / Fail	Crack Ranking	Remaining Life [years]	Dig Ranking
336	0062-00514	10004	51.80	535057.0	iw	cl	Fail	147	0	135
337	0064-00597	10110	8.34	540615.9	aw	cl	Fail	79	0	77
338	0064-00206	10136	45.69	542077.4	aw	nl	Fail	206	0	183
339	0065-00286	10270	45.47	547744.8	aw	cl	Fail	134	0	123
340	0066-00212	10344	53.36	551915.3	aw	cl	Pass		18.7	
341	0066-00221	10345	4.15	551925.2	aw	cl	Fail	202	0	180
342	0067-00706	10450	0.48	557532.8	aw	cl	Fail	33	0	31
343	0068-00082	10509	12.03	560725.7	aw	nl	Pass		6.7	222
344	0068-00280	10552	39.24	562986.4	iw	cl	Fail	19	0	18
345	0068-00313	10556	57.56	563237.2	aw	cl	Pass		11.9	
346	0068-00699	10557	1.20	563239.1	aw	cl	Fail	30	0	28
347	3	10737	5.00	572836.42	IW	LOF	Pass		7.6	
348	14	10737	6.36	572837.78	IW	LOF ID/OD/MW Stacked	Fail	A3	0.0	A
349	15	10737	7.97	572839.39	IW	LOF & crack	Fail	A6	0.0	
350	65	10737	41.98	572873.40	IW	LOF	Fail	A11	0.0	
351	0071-00693	10824	42.33	577647.3	aw	cl	Fail	123	0	113
352	0072-00534	10920	36.82	582709.7	aw	cl	Pass		1.7	196
353	0072-00627	10931	6.36	583228.1	aw	cl	Fail	181	0	162
354	0072-00753	10944	0.83	583911.9	aw	nl	Fail	168	0	151
355	0073-00003	10965	33.42	584890.6	aw	nl	Fail	191	0	170
356	0073-00150	10986	46.13	586020.2	aw	nl	Fail	157	0	142
357	0074-01025	11137	1.96	594059.8	aw	cl	Fail	27	0	25
358	0075-00116	11179	36.01	596293.7	aw	cl	Pass		15.2	
359	0075-00118	11179	42.99	596300.6	aw	cl	Pass		15.2	
360	0075-00124	11180	13.64	596330.5	aw	cl	Fail	199	0	177
361	0077-00393	11357	18.40	606318.4	aw	cl	Pass		5.4	210
362	0077-00428	11360	0.17	606467.6	aw	cl	Pass		13.4	
363	0077-01196	11360	7.63	606475.1	aw	cl	Fail	173	0	155
364	0078-01240	11510	27.19	613949.8	aw	nl	Pass		6.7	223
365	0079-00871	11526	1.06	614806.9	aw	cl	Fail	47	0	45
366	0080-00392	11659	5.87	621729.6	aw	cl	Pass		10.1	247
367	0081-00258	11748	26.52	626503.5	aw	cl	Fail	164	0	147
368	0082-00067	11803	53.93	629537.5	aw	cl	Pass		15.7	275
369	0082-00189	11814	24.61	630095.6	aw	cl	Pass		13.4	262
370	0082-00822	11829	15.76	630916.6	aw	cl	Fail	153	0	138
371	0082-00336	11829	27.17	630928.0	aw	cl	Fail	195	0	
372	0082-00606	11869	24.66	633063.7	aw	cl	Pass		13.4	
373	0082-00614	11869	47.49	633086.5	aw	cl	Fail	95	0	93
374	0082-00765	11886	33.87	633986.2	aw	nl	Pass		7.4	228

12. FIGURES

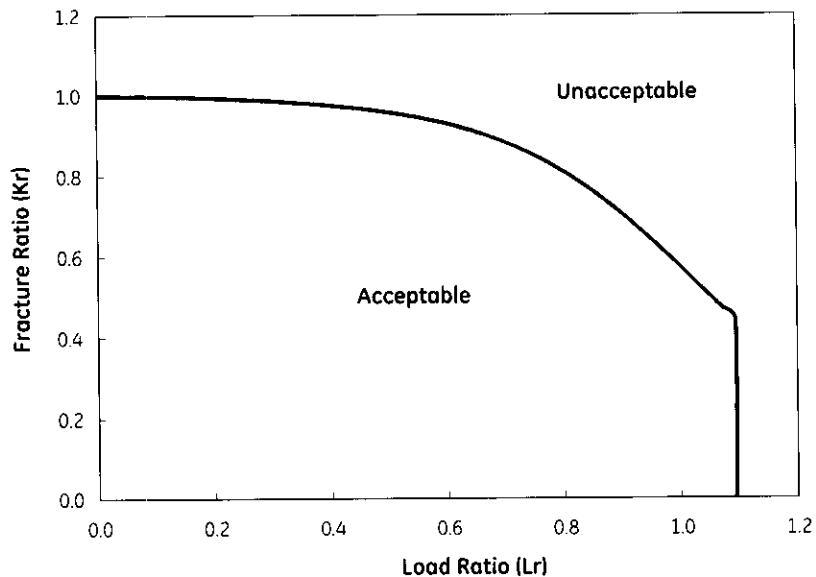


Figure 1: Typical Failure Assessment Diagram Level-II

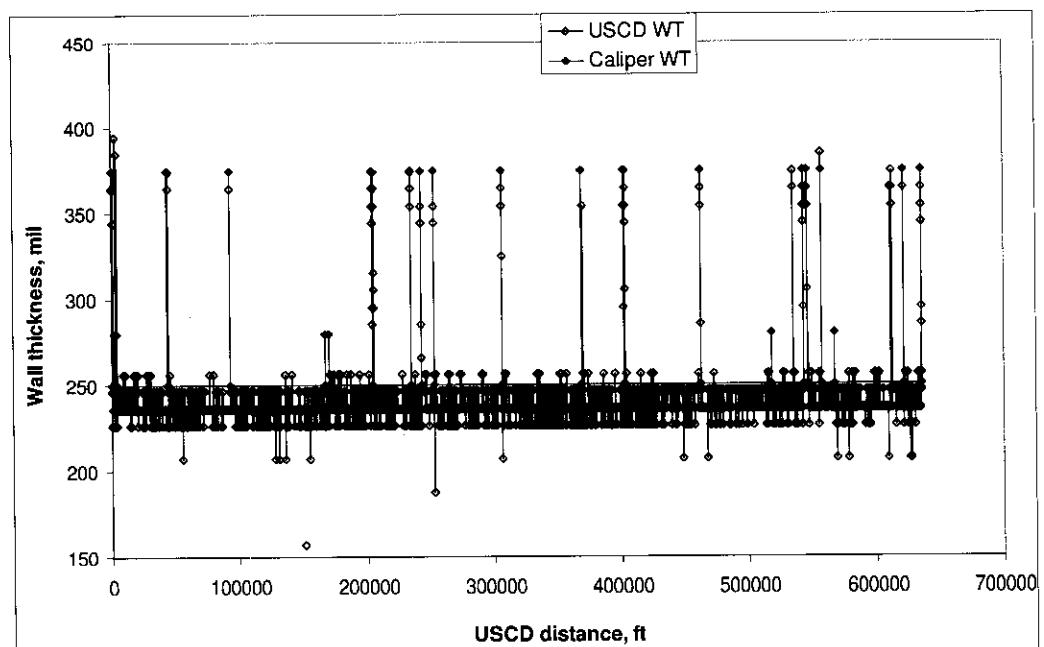


Figure 2: Alignment of nominal wall thickness by USCD distance. The distance for the nominal wall thickness has been linearly corrected.

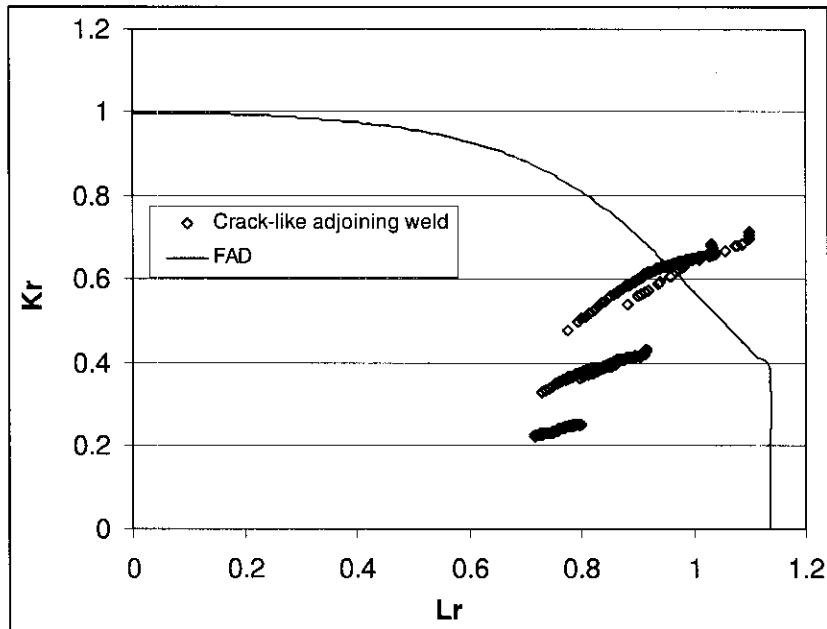


Figure 3: FAD level II assessment of USCD crack-like features adjoining weld (aw) at MOP 1440 psi.

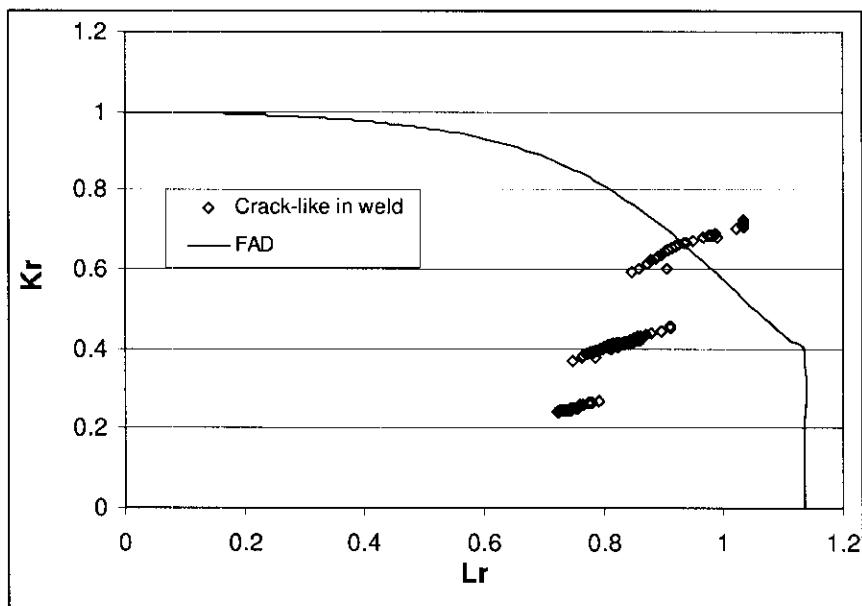


Figure 4: FAD level II assessment of USCD crack-like features in weld or relative position not-decidable at MOP 1440 psi.

Figure includes 10 features reported as in base material, but were assessed conservatively as if they were in weld because the long seam orientation was unclear.

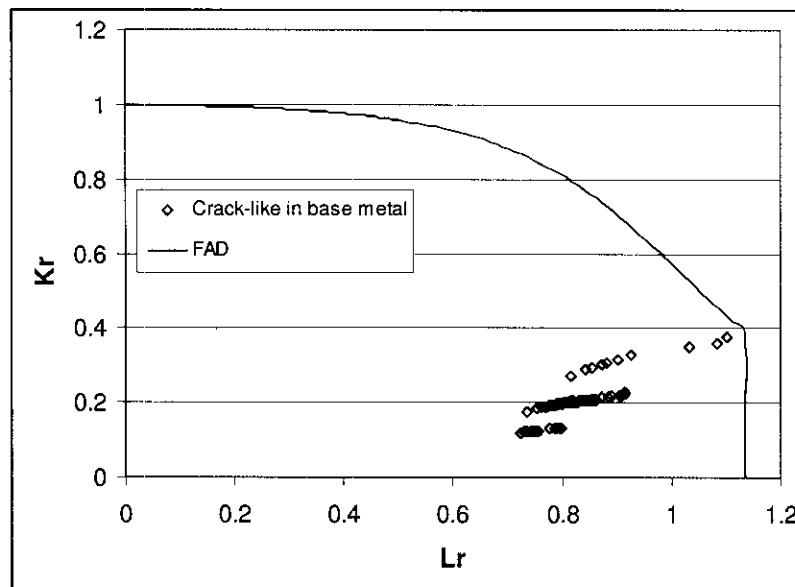


Figure 5: FAD level II assessment of USCD crack-like features in base material at MOP 1440 psi.

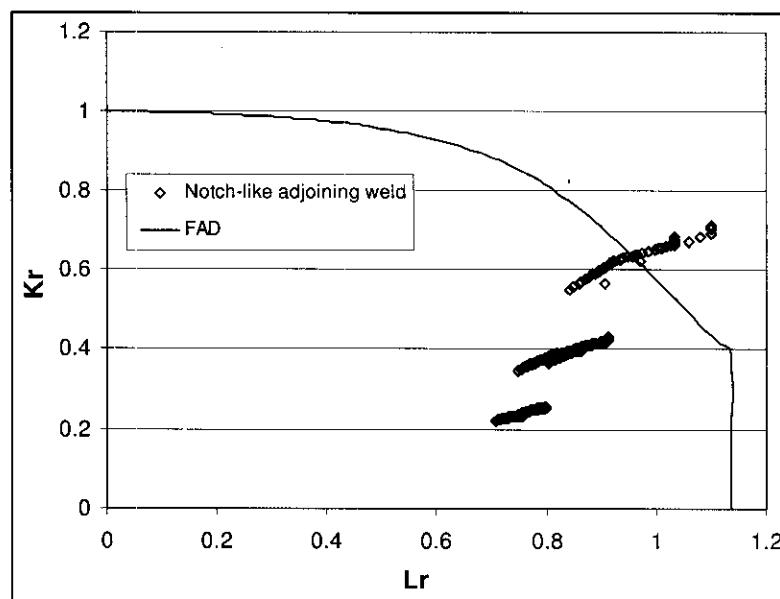


Figure 6: FAD level II assessment of USCD notch-like features adjoining weld at MOP 1440 psi.

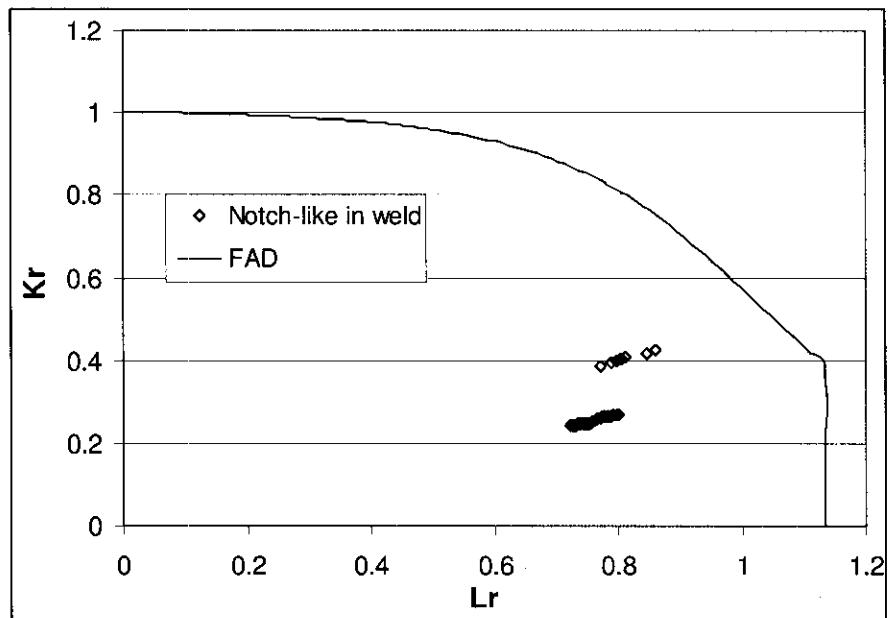


Figure 7: FAD level II assessment of USCD notch-like Indications in weld or the relative position not-decidable at MOP 1440 psi.

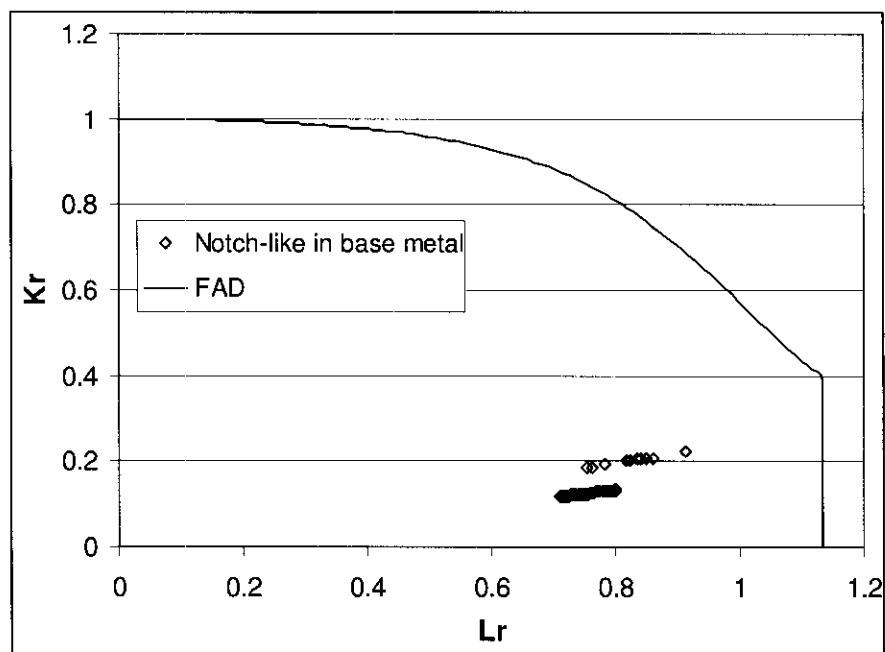


Figure 8: FAD level II assessment of USCD notch-like features in base metal at MOP 1440 psi.

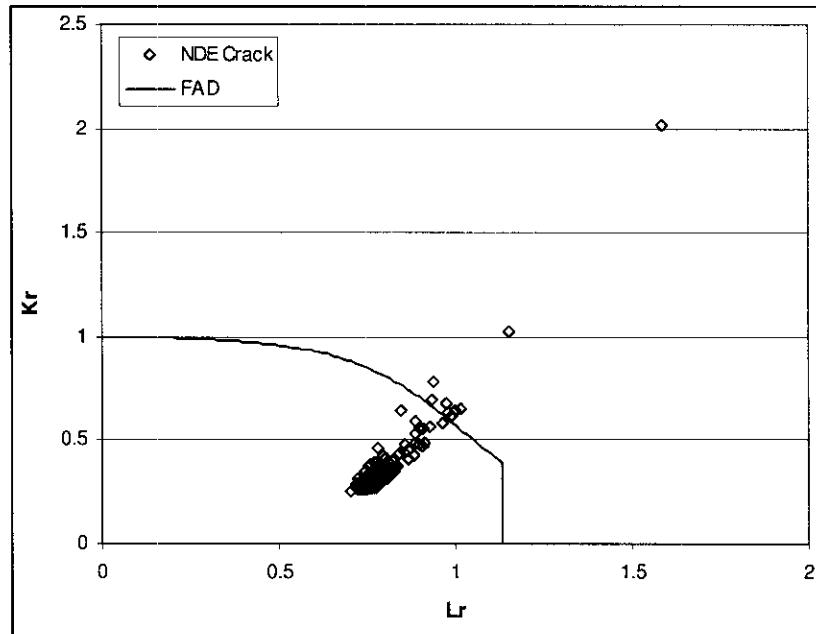


Figure 9: FAD level II assessment of field measured cracks at MOP 1440 psi.

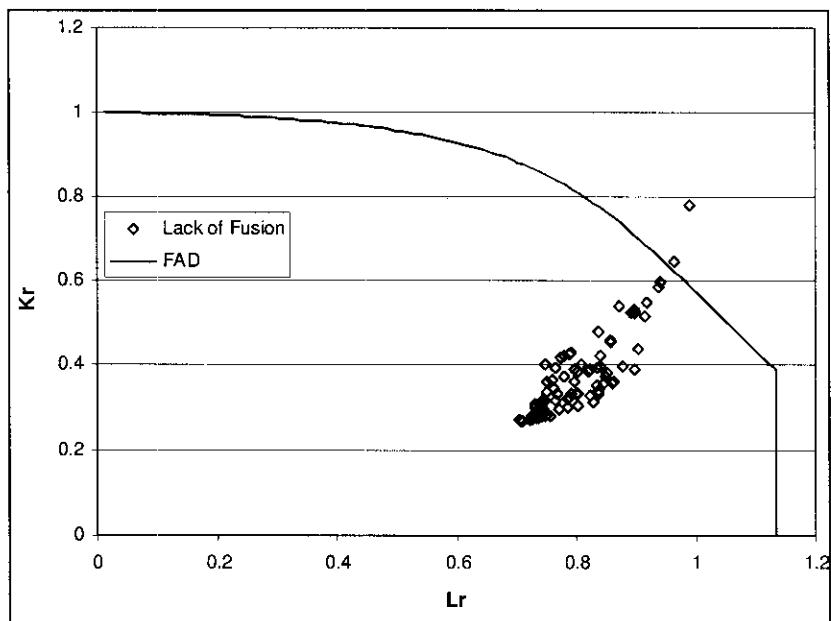


Figure 10: FAD level II assessment of field measured lack of fusion at MOP 1440 psi.

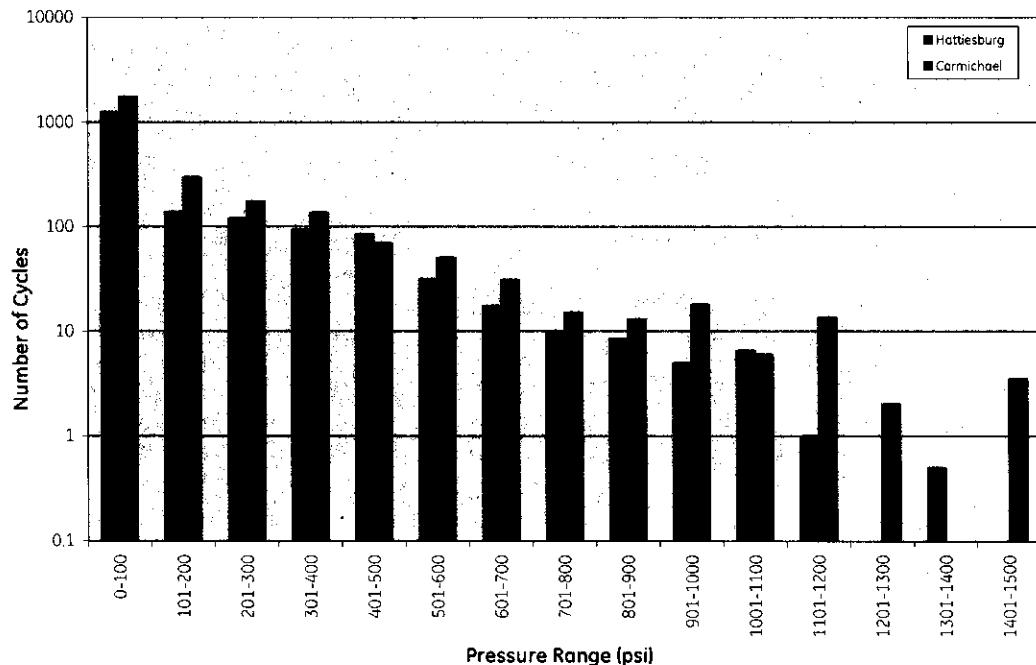


Figure 11: Pressure blocks comparison: Hattiesburg and Carmichael

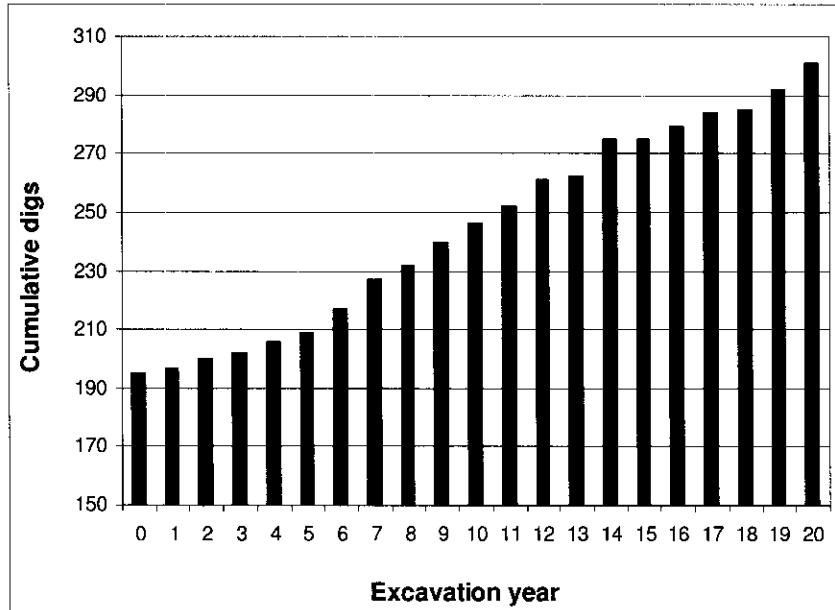


Figure 12: Number of cumulative excavations vs. excavation years. The numbers are based on level II FAD assessment at MOP 1440 psi for USCD crack-like, notch-like features, and field indications, and fatigue assessment. The features in a same pipe joint or in adjoining joints but closer than 40 feet are assumed in one excavation.

13. APPENDIX

13.1 A Description of FAD Level-III/Ductile Tearing Instability Approach

Figure A1 illustrates how a crack remains stable. In the figure, the vertical axis of the FAD is K_r , the ratio of the applied stress intensity factor K (or applied J-integral, or crack tip opening displacement (CTOD)) to the material's fracture toughness K_{MAT} (or J_{MAT} , or CTOD critical). The horizontal axis is L_r , the ratio of the applied reference stress (σ_{ref}) to the yield stress (σ_y). The assessment curve in the figure represents the locus of the predicted failure points for crack-like flaws under a combined condition of crack size, stress and material properties. A cut off on the horizontal L_r axis is incorporated into the assessment to account for localized plastic collapse, that is, $L_{max} = (\sigma_y + \sigma_{uts})/2 \sigma_y$. When an assessment point is initially outside of assessment curve, then drops below the assessment curve as a result of ductile tearing, crack extension would eventually stop. At the assumed operating pressure, these cracks would not result in failure by rupture, even though they were initially outside the assessment curve and exhibited some degree of stable crack extension.

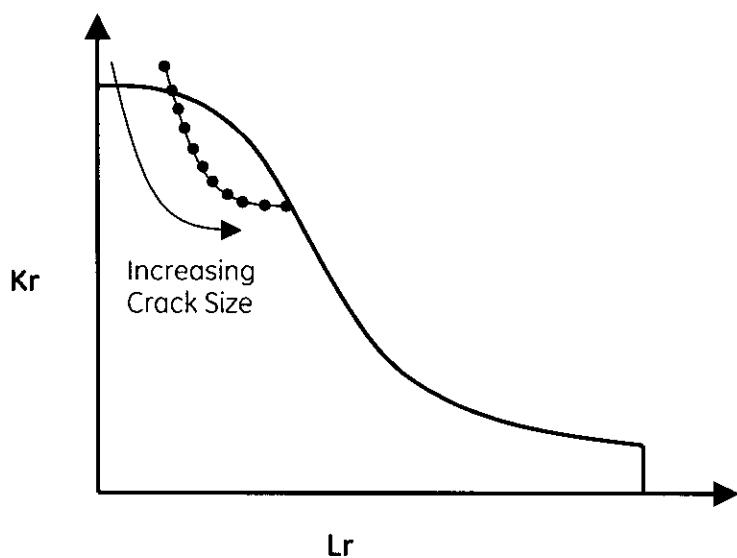


Figure A1: FAD and Crack Stability

When a crack is entirely below the assessment curve it will remain stable; no crack extension will occur as long as the applied load does not increase, as shown in Figure A2. When a crack appears first above and then tangent to the assessment curve, it represents the limiting condition or instability for a particular crack size and load level. Any increase in this load would result in rupture.

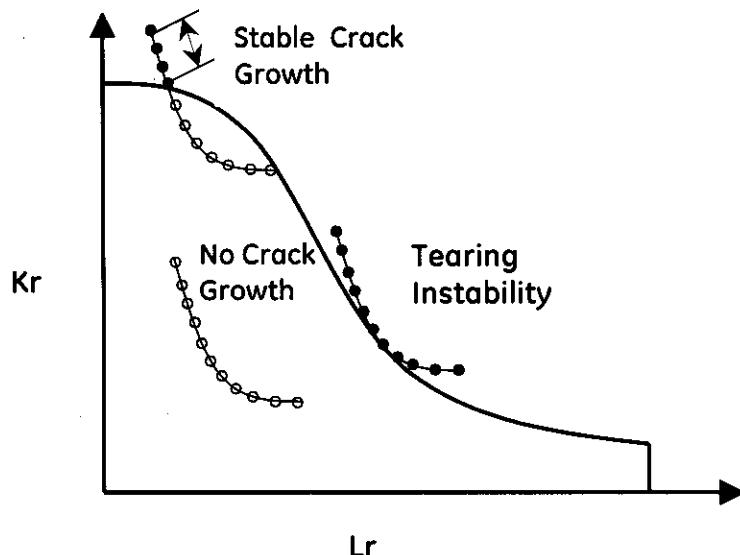


Figure A2: FAD and Tearing Instability Approach

Thus, a crack becomes unstable when the rate of change in the driving force is greater or equal to the rate of change of the material resistance. This tearing instability condition is described by the following relation [1A]:

$$\frac{dJ_{\text{applied}}}{da} \geq \frac{dJ_R}{da} \quad (1)$$

It is assumed that no other form of sub critical crack growth is involved during the tearing, i.e., fatigue or corrosion fatigue and creep. It is believed these forms of crack growth are unlikely to drive the growth of the type of cracking being found in the line, given the current and anticipated operating conditions. If crack growth mechanisms cannot be excluded, this analysis should be applied only to overload conditions. Sub critical crack growth under normal operating pressure should be taken into account to estimate the crack size after a certain service time. In addition, the life cycle calculation is based on sub critical crack growth rate, and the critical size is estimated from tearing instability analysis.

The FAD Level-III curve was defined using the material's true stress-strain behavior, based on the reference stress model [2A]. The material specific FAD is given by:



$$K_r = \left[\frac{E\epsilon_{ref}}{L_r \sigma_{ys}} + \frac{L_r^3 \sigma_{ys}}{2E\epsilon_{ref}} \right]^{-\frac{1}{2}} \quad \text{for } L_r \leq L_{r(\max)} \quad (2)$$

Where:

E = Young's Modulus (MPa:psi)

L_r = Load ratio

$L_{r(\max)}$ = Maximum Value of the load ratio

ϵ_{ref} = Reference strain obtained from the true stress-strain curve

σ_{ys} = Yield stress (MPa:psi)

The true stress-strain curve is obtained by converting the measured engineering stress using the Ramberg-Osgood relationship.



13.2 Depth Comparison between USCD Features and Field Findings

A comparison of the USCD reported depths and the depths based on 41 dig reports [6] has been conducted. The USCD features that have been investigated in field are manually matched with field indications of cracks, lack of fusion, metal loss and sliver by the PAUT measurements. When PAUT measurement is unavailable, the manual measurement is used. A total of 50 features are matched, Table A1. When multiple PAUT depths measurements are available, the maximum value is used. It is found that 45 USCD reported depths are greater than or equal to the field depth measurements. On the basis of this analysis, it can be stated with 90% confidence that the USCD reported depth is greater than or equal to field depth measurement.

Table A1: Comparison of USCD features depth with field depth measurement.

No.	USCD data					Field inspection data				Depth (USCD) - Depth (NDE), %
	Area No.	Pipe No.	Distance [ft]	Est. Depth [%WT]	Depth, wt%	Inspection Method	Field Type	Feature ID		
1	02-00184	149	6800.92	25-40	28.8	Manual	crack	LIN-01	11.2	
2	02-00348	175	8199.83	25-40	24.4	Manual	Lack of fusion	LIN-01	15.6	
3	02-00365	177	8350.58	25-40	18.8	Manual	Lack of fusion	LIN-01	21.2	
4	02-00647	179	8441.98	<12.5	10.0	Manual	corrosion	VOL-01	2.5	
5	02-00494	193	9127.19	25-40	29.6	Manual	Lack of fusion	LIN-01	10.4	
6	03-00547	241	11666.26	12.5-25	26.0	PAUT	crack	LIN-07-02	-1.0	
7	03-00550	241	11667.59	>40	29.6	PAUT	crack	LIN-07-03	70.4	
8	03-00567	241	11684.34	12.5-25	12.8	Manual	crack	LIN-10	12.2	
9	03-01431	295	14585.32	12.5-25	14.0	PAUT	crack	4	11.0	
10	03-01433	295	14586.69	25-40	20.0	PAUT	crack	7	20.0	
11	03-01485	296	14625.28	25-40	20.0	Manual	Lack of fusion	LIN-01	20.0	
12	04-01172	302	14968.39	12.5-25	30.0	Manual	crack	LIN-01	-5.0	
13	04-00071	302	14971.25	12.5-25	16.4	Manual	Lack of fusion	LIN-02	8.6	
14	04-01286	324	16061.59	25-40	48.0	PAUT	crack	20	-8.0	
15	04-01292	324	16066.31	12.5-25	10.0	PAUT	Lack of fusion	56	15.0	
16	04-01293	329	16335.14	12.5-25	24.0	PAUT	crack	25	1.0	
17	04-00490	329	16358.96	12.5-25	24.0	PAUT	crack	53	1.0	
18	04-01216	329	16363.95	12.5-25	18.0	PAUT	crack	88	7.0	
19	04-00501	329	16367.68	25-40	14.0	PAUT	crack	124	26.0	
20	04-01219	332	16527.08	12.5-25	13.6	PAUT	crack	(18)	11.4	
21	04-01294	353	17644.11	12.5-25	20.0	PAUT	crack	3	5.0	
22	04-01233	353	17667.41	25-40	16.0	PAUT	crack	13	24.0	
23	09-01213	761	39467.97	25-40	16.8	PAUT	crack	7	23.2	
24	14-01117	1243	66123.01	25-40	16.0	PAUT	crack	LIN-01/12	24.0	
25	16-01164	1415	74648.45	25-40	11.2	Manual	crack	LIN-01	28.8	
26	44-00889	4077	216007.77	<12.5	10.4	Manual	Lack of fusion	LIN-01	2.1	
27	10-00281	5204	276313.39	>40	49.2	PAUT	crack	5	50.8	
28	10-00283	5204	276315.86	12.5-25	14.0	PAUT	Lack of fusion	10	11.0	
29	10-00287	5204	276324.96	25-40	32.0	PAUT	crack	37	8.0	
30	10-00289	5204	276330.40	25-40	20.0	PAUT	crack	42	20.0	
31	10-00290	5204	276331.43	25-40	36.0	PAUT	crack	48	4.0	
32	11-00550	5326	283042.56	<12.5	9.7	Manual	Lack of fusion	LIN-01	2.8	
33	11-00552	5326	283046.02	12.5-25	9.2	Manual	sliver	VOL-01	15.8	
34	21-00620	6262	333799.75	12.5-25	21.6	Manual	Lack of fusion	LIN-02	3.4	
35	22-00483	6265	333967.72	25-40	32.8	Manual	Lack of fusion	LIN-02	7.2	
36	22-00042	6266	334059.72	<12.5	22.8	Manual	Lack of fusion	LIN-02	-10.3	
37	23-00633	6418	342444.53	25-40	36.0	PAUT	crack	2	4.0	



38	24-00187	6468	345216.15	25-40	36.4	Manual	crack	LIN-01	3.6
39	24-00204	6468	345249.19	>40	25.6	Manual	Lack of fusion	LIN-03	74.4
40	24-00600	6511	347555.14	12.5-25	22.4	Manual	Lack of fusion	LIN-01	2.6
41	24-00604	6511	347560.55	>40	25.6	Manual	Lack of fusion	LIN-02	74.4
42	24-00743	6511	347561.70	25-40	38.4	Manual	Lack of fusion	LIN-03	1.6
43	29-01168	6903	368987.49	25-40	40.0	PAUT	crack	47	0.0
44	29-00117	6903	368993.53	25-40	12.0	PAUT	crack	14	28.0
45	29-01169	6903	368999.78	25-40	12.0	PAUT	Lack of fusion	34	28.0
46	29-00130	6903	369007.39	12.5-25	32.0	PAUT	Lack of fusion	44	-7.0
47	34-00980	7423	396998.13	25-40	24.0	PAUT	crack	2	16.0
48	34-00982	7423	397000.59	25-40	24.0	PAUT	Lack of fusion	5	16.0
49	34-00991	7423	397018.78	>40	20.0	PAUT	Lack of fusion	21	80.0
50	47-00493	8596	459368.07	12.5-25	12.0	Manual	Lack of fusion	LIN-01	13.0



13.3 RainFlow Counting Method

RainFlow counting describes the method used to simplify the complex operational cyclic pressure data recorded at the discharge portion side of the pump station, into a form that can be utilized to predict the fatigue life of the pipeline.

The pressure data, in the form of maximum pressure vs. time, was simplified into blocks of pressure cycles of similar magnitude (Figure A3, (b)) for each year of provided pressure data by employing the RainFlow counting standard technique.

The method is shown schematically in Figure A3. The RainFlow procedure ensures that the maximum possible stress ranges in a sequence are counted [3A]. The waveform is imagined to be a series of rooftops on which rain can flow. It is viewed with the time axis in the vertical position, the starting point being at the top. The rooftop image is produced by representing the stress fluctuations as a triangular waveform. Rules are imposed on the way in which rain can flow such that the waveform is broken down into a number of rain flow paths. The beginning and end of each path define the extremities of a half-cycle.

Rules

With reference to Figure A4, the rain flow starts at the origin (O) and is allowed to flow down the roof until a peak or a trough is encountered. At this point, the rain falls vertically until it reaches another roof, which it then continues down. Rain flow from left to right and right to left is considered. The flow of rain continues until one of the following conditions arises:

- Rain flowing down a rooftop encounters rain falling vertically from a roof above. In Figure A4, rain flow from E to G stops at F for this reason
- Rain falling vertically passes opposite to:
 - a peak which is more positive than, or
 - a trough which is more negative than the peak or trough at the start of the rain flow path being considered
 The origin is regarded as a trough if the stress proceeds in a positive direction. Thus, in Figure A4 the flow path OAG stops after G because the trough at H is more negative than at O. Similarly, path ABE stops because the peak at G is more positive than at A.
- The end of the waveform is reached. In this case, the unfinished flow paths GHKL, LMST and UV would all be considered complete at the end of the analysis.

Each complete flow path is regarded as a half-cycle and half-cycles of equal range are combined to give a complete cycle.

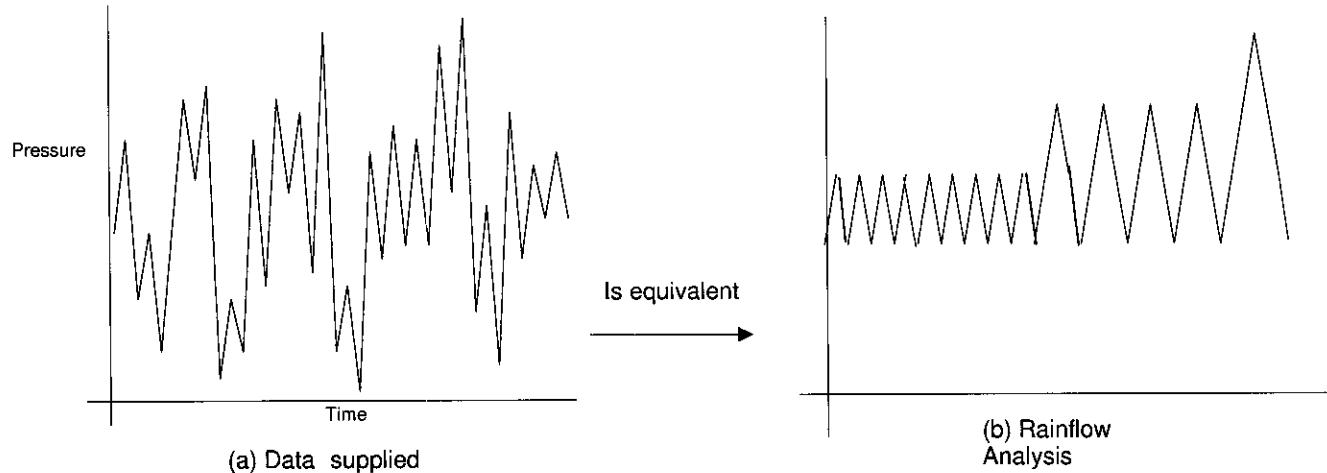


Figure A3: Illustration of RainFlow and Miner's Rule Simplification Procedure

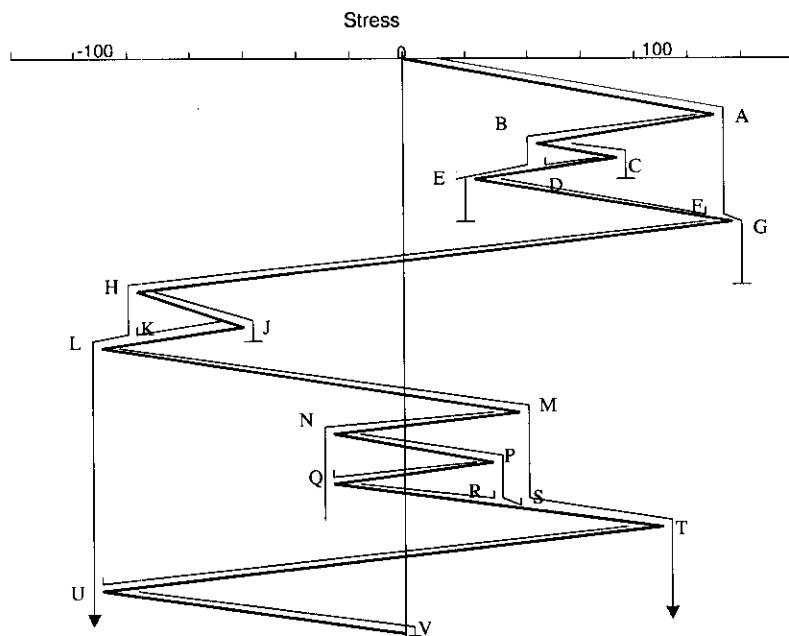


Figure A4: Representation of RainFlow Counting Procedure

REFERENCES:

- 1A. Anderson, T.L, Fracture Mechanics: Fundamentals and Applications, CRC Press LLC, Boca Raton, FL, 1995, pp. 488-489.
- 2A. American Petroleum Institute (API), "Recommended Practice 579, Fitness-for-Service," Section 9, p. 9-20, January 2000.

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3A. Glinka, G., "RainFlow Counting Algorithm for Very Long Stress Histories," International Journal of Fatigue, Vol. 9, No. 3, 1987, pp. 223-228.



13.4 Heading Abbreviations in Feature List

Besides its co-ordinates (distance and circumferential position) each feature is identified by a special ID-number. The Feature List contains the following types of indications:

- indications caused by **crack fields** (cf)
- indications caused by **crack-like defects** (cl)
- indications caused by **metal loss** (ml)
- indications caused by **installations** (ins, useful as 'natural' markers)
- **notch-like** (nl) indications (notch-like indications with the comment *weak* are not included)
- indications of unknown or ambiguous origin (**non-decidable**, nd)
- indications with the comment **strong** (stg) or **striking** (stk)
- dents, deformations (if detected) (geo)
- verified (v), fully documented (d) and examined indications

An *example* of the structure of the Feature List is given in the following table (these are not real features from the inspection):

No.	Area No.	Pipe No.	LW [°]	Wt [mm]	DuGW [m]	DdGW [m]	Distance [m]	Deg [°]	Length [mm]	Est. Depth [%WT]	Rel. Pos.	Rad. Pos.	Type	Comment
18	01-12345	14.00	71	9.5	8.03	3.22	460.07	67	1.6		bm	e	nl	strong; sloping
19	02-54321	18.00	358	7.5	10.50	0.94	619.75	128	2.1	12.5-25	aw	i	cl	striking
20	03-83123	20.00	120	8.0	2.25	8.65	723.62	33	1.4		iw	m	il	Pwl

The following column heading abbreviations are used:

- No. Continuous number
- Area No. Area ID
- Pipe No. Number of pipe joint
- LW Circumferential position of longitudinal weld
- Wt Wall thickness of the pipe joint in mm
- DuGW Distance to upstream girth weld in metres
- DdGW Distance to downstream girth weld in metres
- Distance Distance to area start in metres
- Deg Circumferential position of area in degrees



- Length Length of area in mm
- Est. Depth Estimated depth of crack-like defects is given as a percentage of wall thickness
- Rel. Pos. Relative position of area, with the following values:
 - bm in base material
 - aw adjoining weld
 - iw in longitudinal weld
- Rad. Pos. Radial position of indication, with the following values:
 - e external
 - i internal
 - m mid-wall
 - nd non-decidable
- Type Type of indication
 - cf crack field
 - cl crack-like
 - nd non-decidable
 - ml metal loss
 - nl notch-like
 - il inclusion-like
 - ins installation
 - geo geometry-related



13.5 Nominal Wall Thickness for Dixie 12" Pipeline from Hattiesburg to Demopolis Station

Dixie Pipeline Company provided the following nominal wall thickness sheet.

Pipeline Summary

Tables

Nominal Wall Thickness

The following list provides locations along the pipeline where changes in wall thickness occur. While the MAGPIE inspection tool can easily detect changes in wall thickness, it cannot take direct thickness measurements. Therefore, where wall thicknesses are known, the tool can identify the locations where the thickness changes. Where wall thicknesses are not known, best efforts will be made to estimate thicknesses based on best available data.

Column Heading Definitions:

Column 1	ID#	Each <i>wall thickness change ID</i> is automatically assigned a number in the software. This number is provided to assist the user of <i>PICTRIP</i> software to more easily find any given defect.
Column 2	Time	A reference time from the inspection tool. May also be used to locate features in the <i>PICTRIP</i> software.
Column 3	Distance	Given in either feet or meters, based on contractual agreements, this is the absolute distance measured by the tool from launch.
Column 4	Wall Thickness	The predicted wall thickness in inches or millimeters.
Column 5	PipeType	Type of pipe construction. Electric Resistance Weld (ERW), Seamless (SWE), Lap Weld (LW).
Column 6	Yield Strength (SMYS)	Specified Minimum Yield Strength - A required strength level that measured yield stress of a pipe material must exceed, which is a function of pipe grade. The measured yield stress is the tensile stress required to produce a total elongation of 0.5 percent of a gage length as determined by an extensometer during a tensile test.
Column 7	Safety Factor	(or design factor) Typically 0.72 per ASME B31. In setting the safety factor, due consideration has been given to and allowances made for the manufacturing tolerance and maximum allowable depth of imperfections provided for in the specifications.
Column 8	Length of Segment	The length of the pipe for the specified wall thickness, measured in feet or meters.



Nominal Wall Thickness

Magpie Systems Inc.

ID#	Time	Distance (ft)	Wall Thickness	PipeType	Yield Strength (SMYS)	Safety Factor	Length of Segment (ft)
<i>Dixie - 12" ID/OD Hattiesburg Station to Demopolis Station</i>							
110000000	3163.50	0.00	0.250	ERW	52000	0.72	442.00
110000001	3215.64	442.00	0.375	ERW	35000	0.72	216.09
110000002	3239.80	658.09	0.250	ERW	52000	0.72	1,209.03
110000003	3381.30	1867.13	0.280	SEAMLESS	35000	0.72	2,365.35
110000004	3657.47	4232.48	0.250	ERW	52000	0.72	39,941.18
110000005	9584.86	44026.66	0.375	SEAMLESS	35000	0.72	267.77
110000006	9626.49	44234.43	0.250	ERW	52000	0.72	46,328.14
110000007	17249.04	92722.58	0.375	ERW	35000	0.72	52.20
110000008	17257.77	92774.78	0.250	ERW	52000	0.72	75,136.06
110000009	28632.97	167910.83	0.280	ERW	35000	0.72	62.04
110000010	28841.87	167972.87	0.250	ERW	52000	0.72	3,629.49
110000011	29175.09	171602.36	0.280	ERW	35000	0.72	57.17
110000012	29183.84	171659.53	0.250	ERW	52000	0.72	33,707.60
110000013	35070.57	205367.13	0.375	ERW	35000	0.72	691.44
110000014	35192.14	206058.36	0.250	ERW	52000	0.72	29,833.37
110000015	40145.49	233891.93	0.375	SEAMLESS	35000	0.72	329.23
110000016	40198.97	236221.16	0.250	ERW	52000	0.72	7,637.29
110000017	41439.32	243858.45	0.375	ERW	35000	0.72	248.09
110000018	41480.50	244106.54	0.250	ERW	52000	0.72	9,905.41
110000019	43125.06	250111.95	0.375	ERW	35000	0.72	49.99
110000020	43133.79	254061.94	0.250	ERW	52000	0.72	54,014.40
110000021	52490.67	308076.35	0.375	SEAMLESS	35000	0.72	37.58
110000022	52496.95	308113.93	0.250	ERW	52000	0.72	63,018.06
110000023	62889.87	371313.99	0.375	ERW	35000	0.72	49.68
110000024	62598.36	371181.87	0.250	ERW	52000	0.72	33,100.24
110000025	67986.50	404282.11	0.375	ERW	35000	0.72	690.01
110000026	68076.35	404972.13	0.250	ERW	52000	0.72	60,025.33
110000027	78157.78	464997.45	0.375	ERW	35000	0.72	52.92
110000028	78166.69	465050.37	0.250	ERW	52000	0.72	56,335.24
110000029	88334.54	520385.61	0.280	ERW	35000	0.72	45.19
110000030	88342.80	520430.80	0.250	ERW	35000	0.72	25,530.69
110000031	92640.86	543961.99	0.375	ERW	52000	0.72	3,550.32
110000032	93169.01	549511.82	0.250	ERW	52000	0.72	10,969.42



Nominal Wall Thickness

Magpie Systems Inc.

Dixie - 12" ID/DD Hattiesburg Station to Demopolis Station

ID#	Time	Distance (ft)	Wall Thickness	PipeType	Yield Strength (SMYS)	Safety Factor	Length of Segment (ft)
11000033	94850.73	560481.24	0.325	SEAMLESS	35000	0.72	42.39
11000034	94857.63	560523.63	0.250	ERW	52000	0.72	9,797.98
11000035	96477.02	570321.61	0.280	ERW	35000	0.72	60.24
11000036	96487.33	570381.85	0.250	ERW	52000	0.72	54,780.10
11000037	106191.38	625161.95	0.375	SEAMLESS	35000	0.72	93.85
11000038	106208.75	625255.79	0.250	ERW	52000	0.72	13,490.36
11000039	108610.93	638746.15	0.375	ERW	35000	0.72	56.26
11000040	108621.06	638802.42	0.250	ERW	52000	0.72	202.33
11000041	108656.02	639004.75	0.375	SEAMLESS	35000	0.72	11.05

Wall Thickness Summary

Wall Thickness	PipeType	Total Length ft	Total Length (miles)	Percent of Total Distance
0.250	ERW	629,987	119.316	98.6%
0.280	ERW	225	0.043	0.0%
0.280	SEAMLESS	2,365	0.446	0.4%
0.375	ERW	5,657	1.071	0.9%
0.375	SEAMLESS	782	0.148	0.1%